UBC Social Ecological Economic Development Studies (SEEDS) Student Report

# Sustainable Landscapes at UBC: Assessing the soil and vegetation at Sustainability Street using criteria established under the Sustainable Sites Initiative

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**University of British Columbia**

**ENVR 400**

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# Sustainable Landscapes at UBC

## Assessing the soil and vegetation at Sustainability Street using criteria established under the Sustainable Sites Initiative

Source: Design Center for Sustainability, University of British Columbia (2009).

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# Acknowledgements

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# 1. EXECUTIVE SUMMARY


As a part of UBC's sustainable practices, our community partner, UBC Social Ecological Economic Development Studies (SEEDS), and Campus Landscape Architect Dean Gregory, are interested in implementing environmental benchmarks and guidelines for sustainable landscape architecture. This is similar to how the campus uses Leadership in Energy and Environmental Design (LEED) certification to ensure new buildings meet sustainability and efficiency standards. Our project marks the first time at UBC where guidelines were used to assess a campus landscape, in hopes of

producing a model sustainable landscape that could lead current industrial development to a more sustainable direction. Our team utilized the Sustainable Sites Initiative (SITES) Guidelines and Performance Benchmarks 2009 to assess the state of soil and vegetation both for the current Sustainability Street and for its renovation plans.

The assessments were performed according to Section 4: Site Design -- Soil and Vegetation of the guidelines, with a specific focus on the management and restoration of soil and native plant species on site. The mandatory guidelines (prerequisites) and optional features (credits) that we covered include:

- Control and management of known invasive species found on site (Prerequisite 4.1)
- Use of appropriate, non-invasive plants (Prerequisite 4.2)
- Development of a soil management plan (Prerequisite 4.3)
- Preservation and restoration of appropriate plant biomass on site (Credit 4.6)
- Use of native plants (Credit 4.7)
- Restore plant communities native to the ecoregion (Credit 4.9)

In accordance to SITES, our analysis of Sustainability Street's current state and its renovation plans show the following:

- 87% of the current Sustainability Street is covered by non-native plants. Of the non-native plants, 9% are problematic noxious weeds. We have recommended a new active and realistic management plan to control invasive plants in order to receive higher score for prerequisite 4.1.
- In general, the new planting plan adequately addresses the SITES guidelines and will score well in prerequisite 4.2, credit 4.7 and credit 4.9. Specific recommendations regarding locations of planting are made to further improve each plants' long term suitability.
- Specifications on the new planting plan fully addresses SITES concerns for prerequisite 4.3–the soil management plan, and no further recommendations are necessary.
- The new planting plan shows an improvement in establishing higher plant density and achieves a high score according to the guidelines listed under credit 4.6.

**Overall, the plans for Sustainability Street meet requirements in Section 4: Soil and Vegetation in SITES (2009). However, the feasibility of a SITES certification for Sustainability Street will ultimately depend on resources available, design goals other than ecological service restoration, and external factors affecting the site plan.**

# 2. TEAM

**Richard Chan**
Richard specializes in ecology and conservation, and has great interest in urban sustainability. Through his academic pursuits in ecology, he has gained knowledge about ecological relationships such as energy flow, nutrient cycling, and the carbon cycle, in addition to developing adept skills in field work, databasing, analysis, management, and report writing. He was able to use his knowledge of conservation and his extracurricular interests in art and design in this project.

**Victoria Lam**
Victoria is an Environmental Sciences major with land, air and water specialization. She has a background in ecology, meteorology and oceanography, as well as a casual interest in gardening. She honed her expertise in this project by analyzing environmental data of an urban landscape, helping to restore its ecological health and attain UBC's sustainable goals.

**Beverly Law**
Beverly is in land, air and water area of concentration with some background in meteorology and oceanography. She has relevant experience and knowledge of field data collection and computer programming from previous courses taken (BIOL 203, 306, EOSC 211). This project provided her the opportunity in applying knowledge outside the classroom setting.

**Diane Lee**
Diane has ecology and conservation area of concentration with general background knowledge on oceanography and hydrology. She has experience in working outdoors to sample in both forest and the ocean. Throughout ecology course works, she gained experience in collecting data and analyzing it using computer software.  This project allowed her to apply her knowledge to the field project.

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# 3. INTRODUCTION

## *3a. Project Overview*

### Context

Known for its environmental awareness, UBC strives to reduce its ecological footprint through "effective energy, water, waste, food systems and transportation management, green building design, and green research initiatives" (Campus Community Planning, 2013). The campus' sustainable initiatives have so far been met with success. For instance, a new UBC policy in 2008 was implemented to ensure that all the new buildings must be built to meet the internationally accepted LEED Gold certification. Currently 3 buildings have been awarded the LEED Gold certification, while the Center of Interactive Research on Sustainability (CIRS) was awarded a LEED Platinum certification (University of British Columbia Sustainability, 2013). 11 other new buildings have currently pending LEED certifications.

However, the design and construction of UBC's vast landscape, unlike its building infrastructure counterparts, is not regulated by any quantifiable sustainable certifications or guidelines. As such, the selection of plants, building material, etc. depends largely on the skills, expertise and personal interpretation of a designer in creating a sustainable landscape, which may or may not be sustainable when considered from a quantifiable and objective perspective. In this project, we used a quantifiable sustainable guideline, Sustainable Sites Initiative (SITES) Guidelines and Performance Benchmark 2009, in one of the first attempts to use sustainable guidelines to assess landscapes at UBC.

### Sustainability Street

The landscape we assess for this project is UBC's Sustainability Street, located south of CIRS on Stores road (Figure 3.1). Sustainability Street slopes on average at an approximately 5 - 30 % gradient to the southwest. Prior to logging in the 1890s, the land now occupied by the university was a Coastal Western Hemlock coniferous forest, consisting primarily of Douglas-fir, Western hemlock, and Western red cedar. The forests on the site were cleared by 1925 (Figure 3.2). Post-clearing, the development of the university can be estimated using aerial photos. A series of aerial photos shown on Figure 3.2 from 1925 shows the progression of development surrounding Sustainability Street from a pasture-like, cleared environment into dense buildings and landscapes.

Intended to serve as the model sustainable landscape that accompanies UBC's model sustainability building CIRS, Sustainability Street was originally built in 2006 with the purpose of collecting stormwater, filtering waste water and generating energy. It was to use a closed loop system that collects, filters, and treats stormwater, and use geoexchange technology to replace heating and cooling sources of buildings. On top of that, it was intended to "highlight the connections between ecosystems, infrastructure, and the urban environment while showcasing innovations in sustainability" (Campus Community Planning, 2013; Design Center for Sustainability, University of British Columbia, 2013).

The street now, however, appears to no longer drain properly, and has fallen short of one of its intended purposes: to filter wastewater. Aside from some occasional trees and shrubs, the street is largely covered by grass with a wide array of exotic weeds (See section 5: Invasive species and management), providing minimal ecosystem services. As such, our community partner, the UBC Social Ecological Economic Development Studies (SEEDS), along with Campus Landscape Architect Dean Gregory, are looking for ways of reviving the street with revised plans and renovations, such that it can become a leading example of sustainable urban development. New designs have since been developed in 2013 (Kiest, 2013).

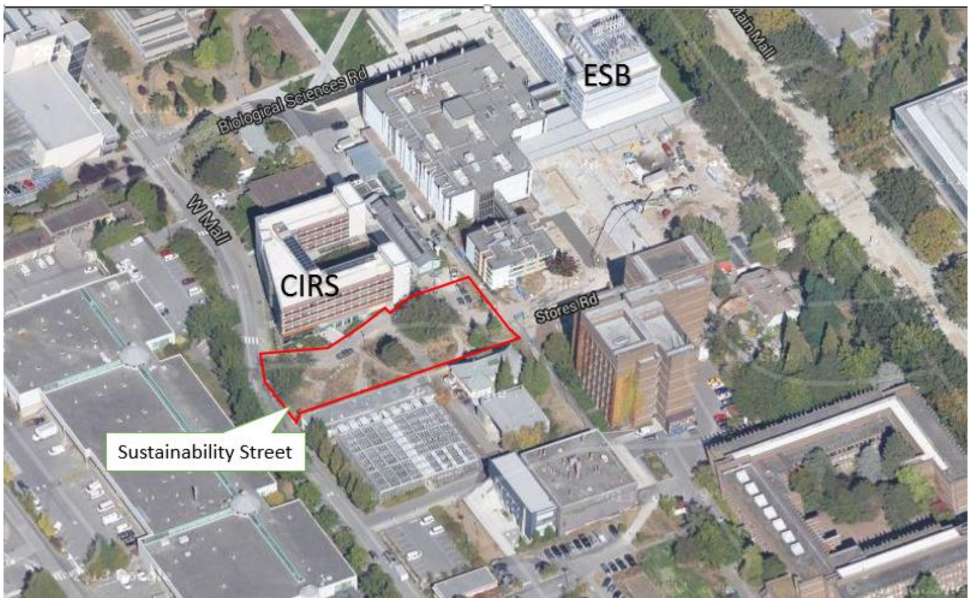


**Figure 3.1.** Map showing location of Sustainability Street. Adapted from Google Earth. The project study area in Sustainability Street is enclosed in red.

## The Project

For this project, we analyzed the site using SITES Guidelines and Performance Benchmarks 2009, Section 4: Site Design -- Soil and Vegetation. Assessments are made for soil and vegetation of (1) Sustainability Street at present (Figure 3.3) and (2) the new site design (Figure 3.4) that outlines plans for renovation. Based on our analysis, we provide recommendations for the new site design to UBC Campus & Community Planning.

Three of the SITES assessment guidelines are mandatory (prerequisites), and as such are integral to our project:

- Control and management of known invasive species found on site (Prerequisite 4.1)
- Use of appropriate, non-invasive plants[1] (Prerequisite 4.2)
- Development of a soil management plan (Prerequisite 4.3)

The other assessment guidelines are not mandatory, but would potentially increase the credits of Sustainability Street. Not all credits are suitable or applicable to Sustainability Street; for

[1] **Non-invasive plants**: plant species that are not officially documented as invasive species or noxious weeds under B.C.'s Ministry of Agriculture (2013). Species do not necessarily have to be native, provided they are appropriate for site conditions, climate, and design intent..

example, it is not appropriate to use Credit 4.8: Preserve native plant communities existing on site. There are virtually no native plants on the street, and hence no native plant communities to preserve. Tentatively, based on the suitability of Sustainability Street to the individual credits, we would assess:

- Preservation and restoration of appropriate plant biomass on site[2] (Credit 4.6)
- Use of native plants (Credit 4.7)
- Restoration of plant communities native to the ecoregion[3] (Credit 4.9)

Through assessing the aforementioned guidelines using the methods provided in the SITES "Guidelines and Performance Benchmarks 2009" document, we establish approximately where Sustainability Street stands in the SITES criteria and identify its strengths and weaknesses in terms of soil and vegetation. This assessment can inform and facilitate decision-making for designers and developers, such that they may accomplish their goal of producing a leading example of urban sustainability.

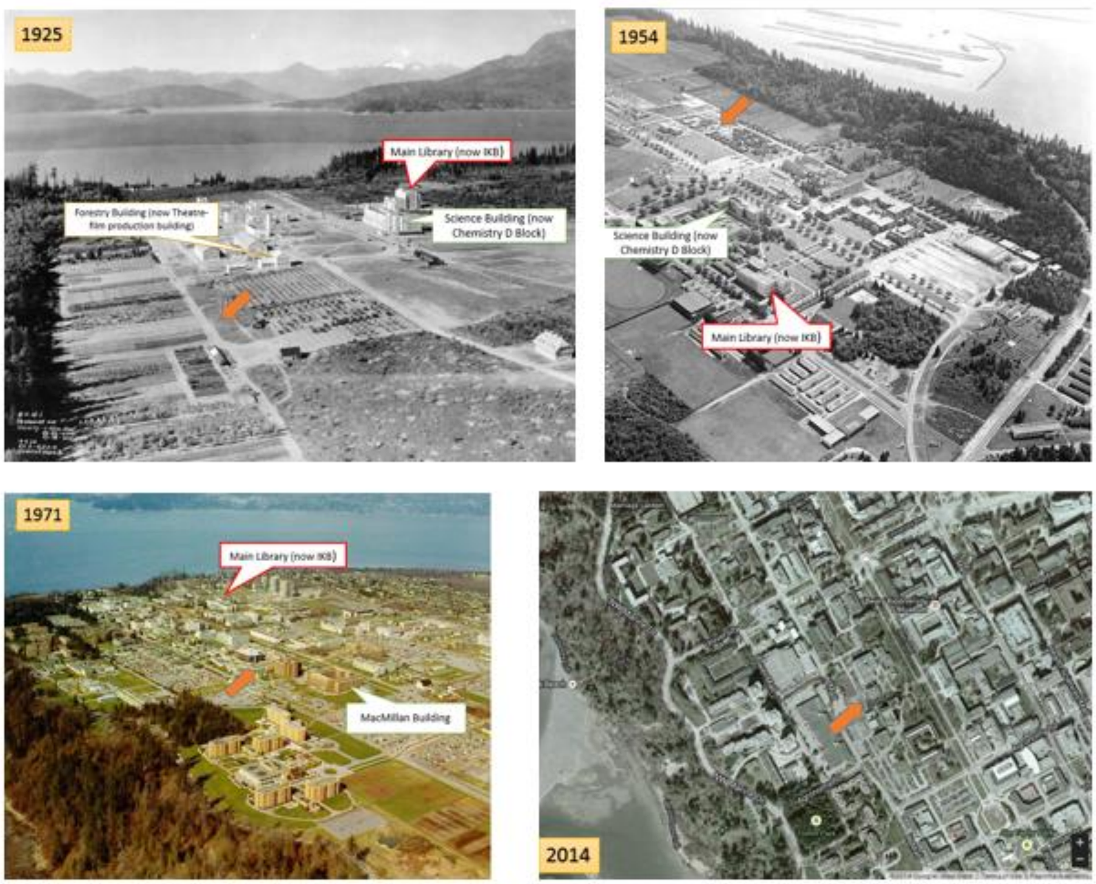


**Figure 3.2.** UBC aerial photos on 1925, 1954, 1971, and 2014. The location of Sustainability Street is estimated using historical landmarks and is indicated by an orange arrow. The original forests on site was cleared by 1925 (top left). Despite building developments in proximity of the street, the street was likely left as lawn or pasture post-clearing (bottom).[4]

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[2] **Appropriate plant biomass**: determined by Biomass Density Index, density of plant layers covering the ground, calculated using guidelines in Sustainable Sites Initiative (2009).

[3] **Native plant communities**: plant species composition and structure similar to the native ecoregion (Vancouver). Thus, Credit 4.9 differs Credit 4.7 as it examines the percentage composition of native plant communities, not individual native plants.

[4] [UBC Aerial Photographs in 1925, 1954 and 1971]. Retrieved March 12, 2014, from: Dean Gregory.
[UBC Aerial Photograph in 2014]. Retrieved March 12, 2014, from: Google Earth

**Figure 3.3.** The current condition of the site. Photo taken by the team in March 2014.

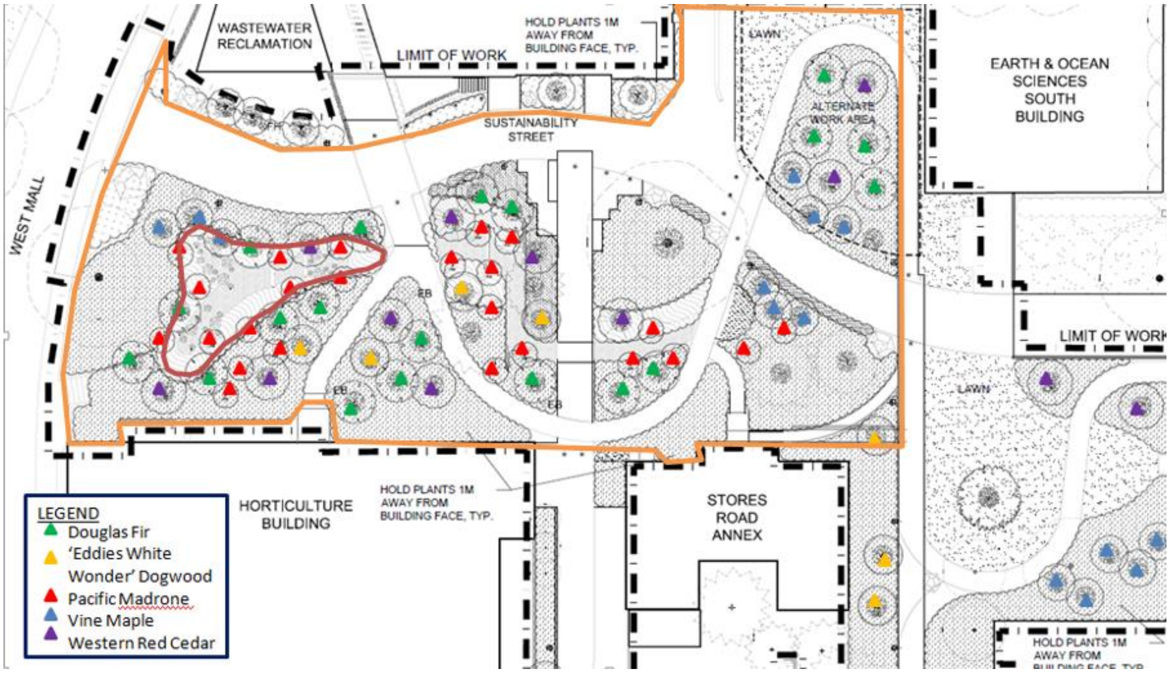



**Figure 3.4.** Planned site plan of Sustainability Street. The area studied in this project is outlined in orange. Stormwater depression is contoured in dark red, with the deepest depression in its centre. Adapted from Kiest, 2013.

### *3b. About SITES*

## History of SITES

World-recognized standards for sustainable building designs such as LEED have been developed since 1998, which encourages the design of "green buildings". Environmental stewardship initiatives for gardens have also been developed in the United States (e.g. the YOUtopia program), with the goal of reducing climate impact through guidelines on water conservation, composting, restoring ecosystem services, etc. (American Public Gardens Association, n.d.). However, there has not previously been a rating system developed with the purpose of promoting sustainable landscapes.

A partnership between the American Society of Landscape Architects, the Lady Bird Johnson Wildflower Center at the University of Texas at Austin, and the United States Botanic Garden, SITES was being developed in the United States by leading sustainability experts, scientists, and designers, as well as hundreds of citizens' input. LEED published by Canada Green Building Council (2013) were used as a template by SITES. SITES aims to modify LEED so the landscapes (with or without the buildings) can also be assessed. It is recommended by the SITES committee for future building projects to achieve SITES guidelines in accordance with LEED.

In 2009 the Sustainable Sites Initiative (SITES), the very first rating system created to evaluate sustainable landscapes, was released (Calkins, 2012; United States Botanical Garden, n.d.). A newer version, SITES v2, which incorporates users' feedback, will be published in 2014.

## Purpose of SITES

The primary objective of SITES is to "build sustainable design practices that meet the needs of the present, without compromising the ability of future generations to meet their own needs" (Sustainable Sites Initiative, 2009). The initiative was developed with the vision of transforming ways which we design landscape, such that landscapes created would be able to support and nourish future generations (United States Botanical Garden, n.d.).

SITES is a rating system that serves to guide, measure and recognize sustainable land design, construction, operations and maintenance practices. It evaluates the sustainability of landscapes, and advocates the restoration of ecosystem services. It emphasizes that sustainable landscapes can not only protect the environment, but also enhance human health, well-being, and are economically cost-effective (Sustainable Sites Initiative, 2009).
SITES attempts to assess the sustainability of landscapes based on the following criteria: (i) site selection, (ii) pre-design assessment and planning, (iii) site design - water, soil and vegetation, material selection, human health and well-being, (iv) construction, (v) operations and maintenance, (vi) monitoring and innovation.

## Goals of SITES

SITES guidelines have been used to evaluate over hundreds of small-scale to large-scale projects. Examples with successful plant management include the Clinton Beach Park in

Whidbey Island, Washington and the High Point Project in Seattle, Washington. The Clinton Beach Park removed all of the invasive plants and re-vegetated the park with native and adapted species. Irrigation is no longer required as the grass areas were seeded with special low-water mix. The use of native and adapted plants at the High Point Project reduces future maintenance needs and improves irrigation efficiency. The project also introduced drought-tolerant and site-suitable plants to minimize the need for irrigation and pesticides. Water retention and soil quality have been improved as a result. The High Point project successfully protects the watershed and natural habitat through the restoration of salmon habitat as a result (Sustainable Sites Initiative, 2009).

Many of SITES' goals focus on the preservation or restoration of ecosystem services. Ecosystem services are the goods and services provided by the ecosystem, which directly or indirectly benefit humans (Sustainable Sites Initiative, 2009; Millennium Ecosystem Assessment, 2005). They include climate regulation, air and water cleansing, erosion control, human health and wellbeing, etc. For example, tree communities can regulate local temperature through shading and evapotranspiration, and also provide fresh air through photosynthesis.

Due to the "free", public nature of ecosystem services, their economic value is not appreciated or immediately quantifiable; they are, however, significant. Studies by Nowak, Crane and Dwyer (2002) estimated the economic value of U.S. urban trees to be $2.4 trillion, due to the sheer amount of services the urban trees provide: they sequester carbon, moderate climate and energy, cleanse air and water, slow stormwater runoff, provide habitat for wildlife, etc. Similarly, researchers also estimate the establishment of 100 million mature trees in U.S. residential areas to save about $2 billion per year due to reduced energy cost (Akbari *et al*., 1992). Healthy ecosystems and the services they provide are not only environmentally sound, healthy for humans, but also hold long term economic benefits.

# 4. INVASIVE SPECIES AND MANAGEMENT

## *4a. Background information*

### Invasive species, noxious weeds, and exotic plants

**Invasive species** are arguably the most dominant factors in reducing ecosystem health and functions. SITES (2009) defines invasive plants as plants that are not native to the ecosystem and are likely to cause economic or environmental harm. Invasive plants have the potential to reproduce aggressively, disturb wildlife habitat (Kieltyk, 2014), and decrease the native plant diversity. They also have several negative impacts on humans because they are sometimes poisonous or have defensive mechanisms such as prickles that can cause discomfort. These species can spread out naturally by wind or water or by hitchhiking on equipment such as boots. In British Columbia, purple loosestrife, English ivy, dalmatian toadflax, scotch broom, field scabrous and Japanese knotweed (bamboo) are some examples of invasive plants. A more detailed regional list is provided on the government of British Columbia website (Province of British Columbia, 2013).

**Noxious weeds** are invasive plants that have adverse effects on human health, agriculture, and livestock (USDA Forest Service, 2006). BC's noxious weeds are typically introduced to the province and are not grazed by local herbivores. They can often exploit the existing resources and reduce the biodiversity of the area. They can also alter ecosystem processes such as primary productivity, nutrient cycling, decomposition, natural disturbance regimes, and hydrological processes (Harrod, 2001). For example, they can alter nutrient cycling through using up nutrients and water to increase biomass and net primary production. More litter will be produced with higher decomposition rates than the ecosystem with native plants, resulting in the alteration of processes such as N-fixation rates (Ehrenfeld, 2003).

**Exotic plants**, on the other hand, are non-native species that have no foreseeable impacts on the local environment. They are not necessarily considered as invasive plants, but they might be undesirable in the area. By definition, exotic species are species that are introduced either accidentally or deliberately by human actions into places beyond their natural habitat range (Province of British Columbia, 2013). Sustainability Street also has a variety of **horticultural species** planted purposefully for aesthetic purposes (L. Jennings, personal communication, 2014, March 4). These species are not considered a threat, as they have been genetically altered to be more resistant to harsh environmental conditions. Their seeds cannot be dispersed into populations of wild species (L. Jennings, personal communication, 2014, March 4).

### Legislation in regards to noxious weeds (The Province of British Columbia, 2013)

- In Canada, legislations include the Seed Act and the Plant Protection Act. These legislations regulate the weed seed content of crop seeds and limit the import of parasitic plants.
- However, there is no federal noxious weed law that specifically regulates noxious plants for landscape and garden use.

- BC has the BC Weed Control Act, which puts responsibility on all land occupiers to control noxious weeds listed in the regulations. There are 47 plants classified as noxious weeds. These plants must not be transported or seeded to unestablished areas.

**SITES guidelines for invasive species**

| Guideline | Objective |
|---|---|
| **4.1: Control and manage known invasive species found on site** | Requires an assessment of invasive species that exist in landscape architecture and development of active management plan to control damage from invasive plants. |

## *4b. Results and Discussion*

- Currently, there are 24 non-native plants on Sustainability Street and their distribution is fairly random and spread out (Figure 4.2).
- A total of 87% of Sustainability Street is covered with non-native plant species.
    - Exotic plants have the most extensive coverage (54%) along with horticultural species (24%).
    - The noxious weeds: Annual Sowthistle, Buckwheat, and Canada thistle cover a total of 9% of Sustainability Street (Table 4.1)

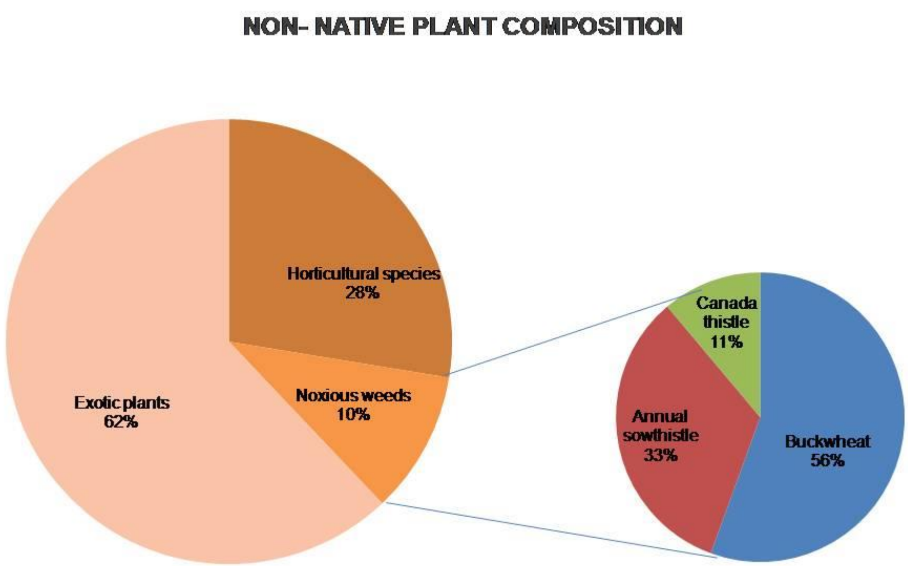



**Figure 4.1.** Non- native plant composition occurring in Sustainability Street based on the field data collected by our team.

| Scientific name | Common name | Status information | % cover in SS |
|---|---|---|---|
| ***Fagopyrum esculentum*** | Buckwheat | Noxious weed | 5 |
| ***Sonchus oleraceus*** | Annual sowthistle | Noxious weed | 3 |
| ***Cirsium arvense*** | Canada thistle | Noxious weed | 1 |
| ***Taraxacum officinale*** | Common dandelion | Exotic | 10 |
| ***Stellaria media*** | Chickweed | Exotic | 7 |
| ***Trifolium repens*** | White clover | Exotic | 7 |
| ***Portulaca oleracea*** | Common purslane | Exotic | 6 |
| ***Senecio vulgaris*** | Common Groundsel | Exotic | 6 |
| ***Plantago lanceolata*** | Narrow-leaved plantain | Exotic | 5 |
| ***Glechoma hederacea*** | Ground ivy | Exotic | 5 |
| ***Buddleja davidii*** | Butterfly bush | Exotic | 4 |
| ***Geranium robertianum*** | Herb robert | Exotic | 4 |
| ***Trifolium incarnatum*** | Crimson clover | Exotic | 2 |
| ***Plantago major*** | Broad-leaved Plantain | Exotic | 1 |
| ***Polygonum aviculare*** | Common knotweed | Exotic | 1 |
| ***Digitaria sanguinalis*** | Crab grass | Exotic | 1 |
| ***Forysythia vahl*** | Forsythia | Exotic | 1 |

**Table 4.1**. Non-native plants on site with their native status, and percentage coverage.

The plant species listed as exotic species in Table 4.1 are not officially documented as noxious weeds in BC provincial and regional lists. However, UBC plant operations states that the following weeds are undesirable on UBC grounds and should be eradicated: *annual bluegrass, barnyard-grass, chickweed, crab grass, clover, couch-grass, dandelion, groundsel, horsetail, mallow, morning glory, prickly lettuce, mustards, oxalis, pigweed, pineapple weed, plantain, shepherd's purse, smart weed, snapweed, sowthistle, stork's bill, and thistle* (UBC technical guidelines, 2013). 5 of the exotic species present on Sustainability Street are on this list. Some weeds can be removed more effectively if the removal procedure involves appropriate timing and methods. For instance, the common dandelion is the most common exotic weed on Sustainability Street. One convenient way of removing dandelions is by hand digging. This dandelion control method is the most effective in spring, before their first seedlings appear. It is important to remove entire dandelion taproot since they can regrow from their roots. For complete removal of dandelions, follow-up hand digging procedures once every few weeks would be necessary (Rhoades, 2014).

Removal of the upper soil layer might remove all of the invasive species for a short period of time. However, without proper management strategies, these exotic species will soon reestablish on the site again (for example, dispersal by wind) and displace native vegetation. Thus, monitoring efforts within the first month of soil disturbance and an invasive species management plan is necessary. With this regard, we have provided an Invasive Species Management Plan in Section 4c: Conclusions and Recommendations.

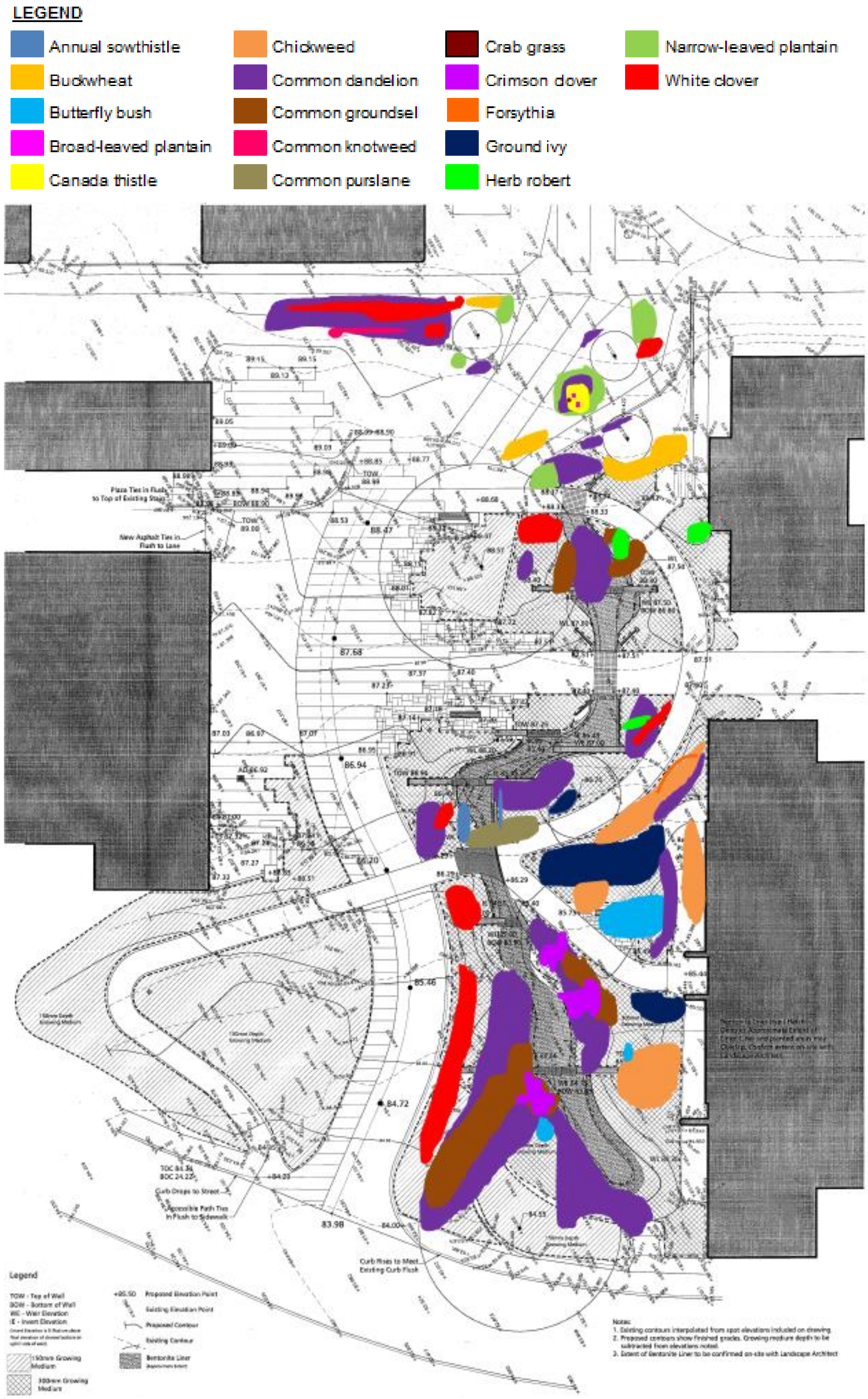



**Figure 4.2.** Map of Sustainability Street based on the field data collected by our team, showing the non-native plants with legend. The methodology for collecting the data is described in Appendix A.

## *4c. Conclusion and Recommendations*

### Invasive Species Management Plan

1. Prevent introduction of noxious weeds

- Quality control of plant material and soil would be necessary. When adding soil or planting trees to Sustainability Street, soil and root balls should not include seeds of invasive plants.
- Since shade can prevent weed growth, planting plan and plant list should include plant species that can thicken up and cover up bare soil ground as soon as possible.
- Mulch should be used to cover the soil during installation of plants after site renovation to prevent any noxious weed seeds from landing and establishing themselves.
- Spacing between each shrub should also be carefully determined in collaboration with UBC Plant Operations for optimal prevention of weed colonization—for example, due to the sparse, spreading physical structure of beach strawberry, a shrub species present on the planting plan, the spacing determined is inappropriate and too sparse. This allows for weed introductions; opportunities like these should be minimized.

2. Eradicate small infestations

- Survey the site twice a month to identify any potential invasive species, and to monitor the health of site plants.
- Surveys should be conducted preferably by on-campus organizations such as Building Operations, the CIRS Green Committee, similar building inhabitant groups, or a volunteer group. Doing this allows for simple small-scale removal of infestations.
- Inspections should be more frequent immediately after site renovation. Inspection could be reduced to once a month after 2-3 months of inspection (the period can be extended or reduced based on the suggestions of the campus landscape designer).
- Detected species should be removed, or kept to a tolerable level. A written and/or photographic record of the specific species that have invaded the site should be kept, perhaps through an online database. This may be useful over the long term, as it would be possible to see which kinds of species tend to frequent the site most.
    - Removal methods of invasive species include:
        1. Mechanical control: hand pulling and cutting (full removal)
        2. Biocontrol: introducing insects which attack the plant (IPM Access, 2000)
        3. Chemical control: application of herbicides (last resort)

3. Educate the community

- Develop outreach material that includes information that can be helpful in identifying invasives, such as photographs of common invasive species found on the site, and descriptions of their characteristics.
- Develop signs around the site giving brief explanations about invasive species, and how to identify common species.
- Provide an on-campus telephone number or website that visitors can visit when they discover potential invasive species growing at the site. A website may also allow visitors to provide feedback, report issues, and learn more about sustainable landscapes.

# 5. NATIVE SPECIES AND COMMUNITIES

## *5a. Background Information*

### Significance of Native Species

The use of native species in local landscapes brings benefits such as providing protective cover, habitats, and food sources for animals and insects. Native species are hardy and adapted to the local environment. Once established, they require low maintenance and little to no pesticides. Water quality would be improved as a result of reduction in use of pesticides. Natives can even control soil erosion and moderate floods and droughts (U.S. Environmental Protection Agency, 2012).

But most importantly, native species help preserve biodiversity. They act to regulate the natural environment and prevent biodiversity loss resulting from biological invasions. Biological invasion is defined to be the disruption of natural ecosystems by the increase in abundance of invasive species, which is also one of the major causes of biodiversity loss (Keane and Crawley, 2002; Vila and Weiner, 2004).

Natives prevent the establishment and growth of invasive species through competitive exclusion (Keane and Crawley 2002).In ecosystems where human perturbation has been introduced, native species are less competitive than invasive species. It might be true that invasive species have inherited greater competitiveness through evolution. However, native species are better adapted to the local environment. In the absence of human perturbation, a healthy native species community could outcompete the invasives and prevent their establishment (Keane and Crawley 2002). If adequate and appropriate native plant species are grown, a sustainable, native environment may be restored.

### SITES guidelines for native species

| Guideline | Objective |
|---|---|
| **4.2: Use of appropriate, non-invasive plants** | Assess each species that would be planted in Sustainability Street, ensuring that all species are suitable for the landscape's climate and design intent |
| **4.7: Use of native plants** | Assess each plant's native status |
| **4.9: Restore plant communities native to the ecoregion** | Assess the composition of native plants that are congruent with the ideal species composition in an undisturbed landscape. |

## 5b. Results and Discussion

**SITES 4.2: Use of appropriate, non-invasive plants**

Overall, species present in the planting plan are appropriate to Vancouver's wet, mild temperate climate. Specific comments about species-specific appropriateness are detailed below.

### *Trees*

All trees present in the planting plan are native to the southern coast of British Columbia (Appendix B). The major canopy trees present, Douglas-fir and Pacific madrone, are sun-loving and thrive in a dry to full-sun environment (Figure 5.1). Planting them in an urban, open environment like Sustainability Street is therefore appropriate, as they would not be under any towering canopy cover.

**Figure 5.1.** Planned planting plan of Sustainability Street showing the plant legend with deciduous trees (Douglas fir, 'Eddies white wonder' dogwood, Pacific madrone, Vine maple, and Western red cedar) and coniferous trees (Douglas Fir, Western Red Cedar). The area studied in this project is contoured in orange. Stormwater depression is contoured in dark red, with the deepest depression in its center.

**Pacific madrone** is naturally found in a narrow band along the south coast of British Columbia; it is an excellent selection for attracting wildlife, such as birds and pollinators (E-flora BC, n.d.). It has fruits that attract birds like waxwings and robins, and a strong honey smell that bees are greatly attracted to (Parish, 1994).

It is typically found in well-drained sites with low moisture— this would typically not be a problem because Point Grey's Bose soils are well-drained (detailed in Section 7: Soil Protection and

Management). But the planting plan indicates that some Pacific madrone would be planted near the depression downslope, where stormwater drains into (Figure 5.2). This may be problematic due to likely moisture accumulation down the depression. Adding to the fact that the tree can be susceptible to diseases and pests such as the madrone canker, it would not be ideal to subject it to unnecessary stress like high moisture content.

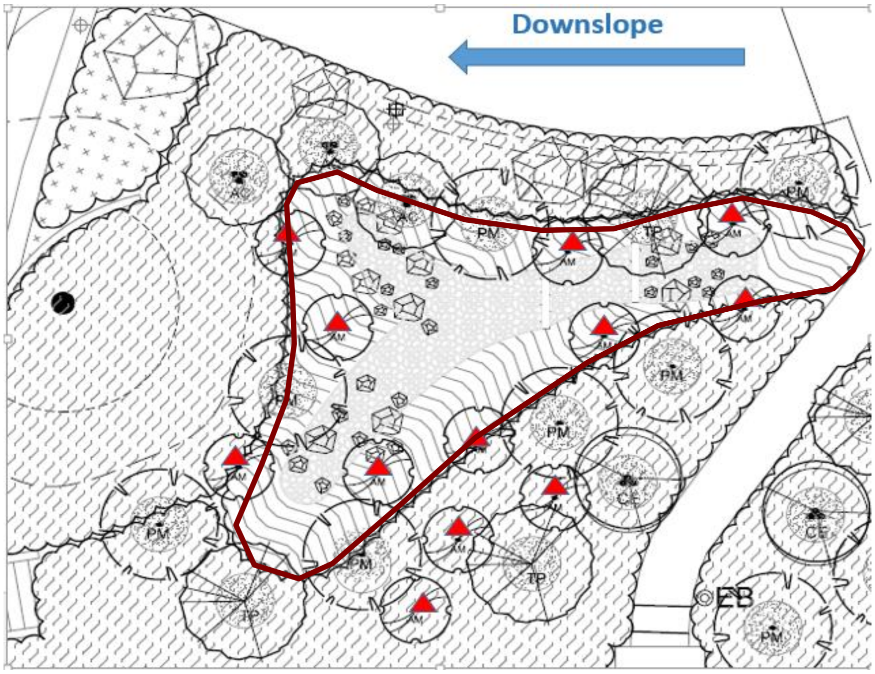



**Figure 5.2.** An excerpt from the planting plan. Red triangles denote locations of Pacific madrone, and zigzag line with a roughly triangular shape shows the area of depression for stormwater flow. As can be seen, the Pacific madrone plantings roughly contour the edge of depression where water drain from.

On the other hand, **Douglas-fir**, while preferring dry environment, also performs well on moist slope environments (E-flora BC, n.d.). There is no need to avoid planting it near the depression. Douglas-fir, like Pacific madrone, is also host to a variety of wildlife species, and its seeds provide food for animals like chipmunks and squirrels.

Another tree that is numerous on the planting plan is **Western red cedar**, a large conifer symbolic to British Columbia. Contrary to Pacific madrone and Douglas-fir, it performs best in moist to wet soil with lots of nutrients (Parish, 1994). As a climax species that occur in dense, thick old growth forests, it is also very shade tolerant (E-flora BC, n.d.). It would be suitable to plant Western red cedar downslope of Sustainability Street because of its preference for moist soil, near the depression for stormwater flow. This would require modifications in the current planting plan, which has Western red cedar spread evenly within the street.

Although Sustainability Street is no old growth forest or park, and therefore not a place where Western red cedar performs best, Western red cedar is also versatile enough to be able to adapt to a variety of planting conditions. As such its planting can be justified due to ornamental, aesthetic appeal and cultural significance (Kruckeberg, 1996).

**Vine maple** is a deciduous shrub or small tree, native to Southwestern British Columbia. Typically it occurs in moist soils on wet sites, and it can tolerate both shade and openings, as long as there isn't excessive sun exposure (Kruckeberg, 1996; Parish, 1994). It is versatile and can be planted under the shade of Douglas-fir─ which Vine maple is naturally adapted to, and on its own─ as a primary succession species (Kruckeberg, 1996; Parish, 1994; E-flora BC, n.d.). On the planting plan, it's primarily planted on its own; we recommend more of them to be planted under shade.

Lastly, **Cornus 'Eddie's White Wonder' Dogwood** may have been included in the planting plan as an accent plant, due to its very showy white flowers in spring, and lush autumn foliage. It is a hybrid of C. *nuttallii* x C. *floria* and is bred to be hardy to the Pacific Northwest (Grant *et al*, 1990). Its fruits provide diet for wildlife, such as pigeons and quails. Dogwood typically grows well in well-drained soils under large conifers like Douglas-fir. In fact, it is known to perform well without summer watering, and would suffer with too much watering (Kruckeberg, 1996). It would not be a good idea to plant the tree downslope near the depression, in case of excess moisture accumulation. Note that dogwoods, with damaged trunks, are easily susceptible to a fatal fungal disease. It is imperative to avoid machinery damage to their trunks in order to minimize maintenance. It is also ideal to plant the tree under shade, as to avoid sun damage to the bark, as it is also susceptible to microorganism damage (Kruckeberg, 1996)

## *Shrubs and grass*

Unlike for trees, the planting plan does not specify where each shrub and grass species will be planted. Instead, it broadly classifies the plants into 3 categories: "lowland shrub mix"—where the shrubs would be planted near the depression, "upland shrub mix"—where the shrubs would be planted elsewhere, and "CIRS grass mix", where grass would be planted on the far eastern side of Sustainability Street. The comments discussed below will be more general and less species-specific, as it is not known where each individual species within the 3 broad categories would be planted.

**The lowland species mix for shrubs**: Isanti dogwood, sword fern, clustered wild rose, and dwarf arctic willow are all adapted to moist conditions (Appendix B). They are appropriate for planting around the depression for stormwater flow, as suggested by the planting plan. Plants adapted to moist to wet conditions are better at taking up moisture, thus assist in reducing stormwater runoff. In general, the lowland species mix is low maintenance, except Islanti dogwood and dwarf arctic willow which are susceptible to a number of pests. They are also not native to British Columbia. However, they are non-invasive and primarily ornamental.

**The upland native mix for shrubs** consists of species that prefer partial-shading. This is appropriate for the new planting plan, which consists of large canopy coverage by a large number of trees such as Douglas-fir, Western red cedar, Pacific madrone, and vine maple. Most species are low to medium maintenance, with not many species having known pests. There is also a large variety of flowering native shrubs which differ in colour, shape, and time of flowering, which provide feeding ground and refuge for pollinators. This shrub mix meets the goal of SITES: to minimize the need of fertilizers, irrigation, pesticides, and the provision of ecosystem services.

**The grass mix** is largely hardy and low maintenance species that can tolerate moist conditions. This is appropriate because the grass, as indicated by planting plan, is located on the very bottom of the slope, where rain runoff would likely accumulate. Only 2 out of 6 species are native, but the rest are known to be non-invasive. Note that there is only a very small percentage area covered by grass, compared to shrubs and trees.

**Other Considerations**

Note that while the aforementioned species are generally appropriate for the landscape according to SITES requirements, the microhabitat which each species is planted in will largely determine the success of planting and maintenance. This is especially important because Sustainability Street has varying terrain and drainage properties at different locations. Once specific locations of shrub plantings are drafted, it is highly advised to consult with UBC Plant Operations for their expertise in determining appropriateness of microhabitat for each individual species.

### SITES 4.7: Use native plants

Through literature search of each species on the proposed planting plan, we found that around 85% of species on the planting plan are documented as "native" (Appendix B). None of the 15% non-native species (e.g. dwarf Arctic willow, Karl Foerster) are invasive; they pose no threat to the environment and are merely ornamental. A fair amount of the non-natives are cultivar (cultivated varieties) with no documented "native status" due to their cultivated origin.

SITES award 3 points for landscapes with between 75 to 100% native plants. Therefore, **Sustainability Street would score 3 out of 4 possible points for Credit 4.7.**

### SITES 4.9: Restore plant communities native to the ecoregion

As the SITES' goal is to restore native plant species and native plant community, we estimated the native vegetation that would both be competitive and thrive in the region using little or no maintenance. This is especially important since two of the goals of Sustainability Street are to become a corridor that bridges the campus to the Pacific Spirit Regional Park, and restore productivity of ecosystem services.

We performed literature search in order to understand the "ideal" species composition that would have been located in the landscape, if human disturbances have never happened. If interested in how the species composition data is gathered, please refer to the methodology section in Appendix A. Note that we are not able to assign scores for Credit 4.9, because the composition and specific placements of shrubs are not yet known. A result percentage of native plant communities cannot be determined.

## Trees

The composition of Douglas-fir and Western red cedar on the Sustainability Street planting plan roughly mimics that of native evergreen forests in Vancouver (Figure 5.3, Figure 5.4). Western hemlock, however, is excluded and replaced by deciduous trees: Vine maple, Eddie's white wonder dogwood, and Pacific madrone.

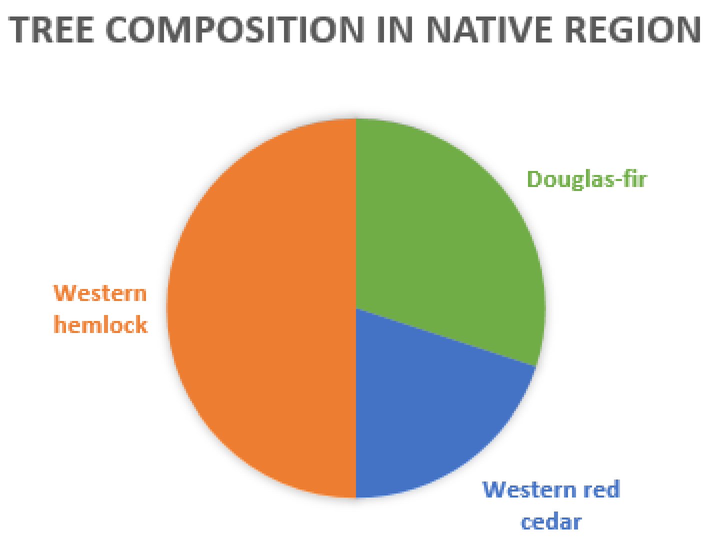



**Figure 5.3.** Tree composition of native ecoregion. Adapted from Land Management Handbook 28, Ministry of Forests, BC (1994).

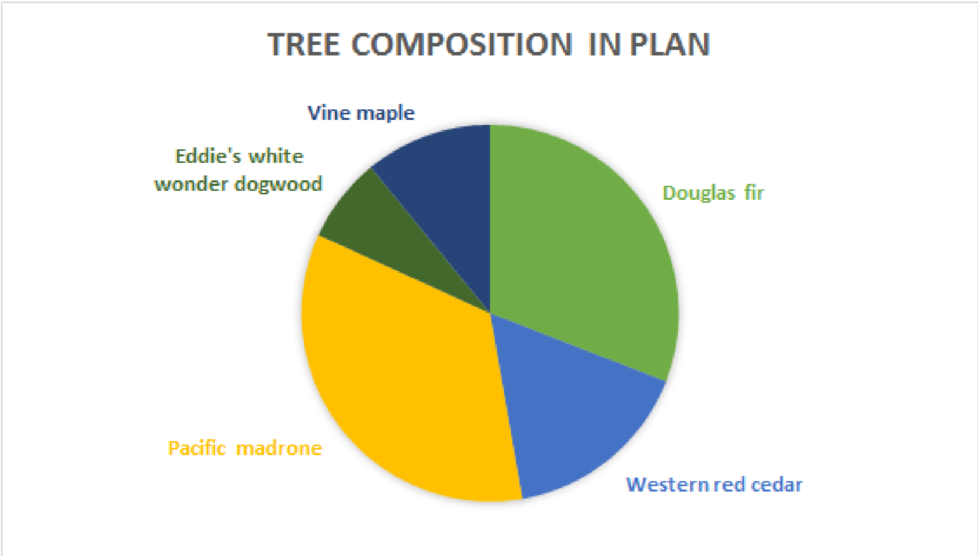



**Figure 5.4**. Tree composition in proposed planting plan.

Naturally, Sustainability Street is located in an urban environment and not a forest, so the environmental condition are different from coastal forests—e.g. less acidic soil and organic matter accumulation, less shade and more open sunlight. The inclusion of other trees native to the coastal community is both ideal and appropriate. For example, Pacific madrone is suited for open areas of sunlight and is also known to occur with Douglas-fir in more open, exposed areas (Parish, 1994; Kruckeberg, 1996). Vine maple commonly exists under canopies of Douglas-fir and dogwood (Parish, 1994; Kruckeberg, 1996). While dogwood is less common in Vancouver, it does well under the shade of Douglas-fir, and would be an appropriate member of the plant community as an accent plant in small proportions (Parish, 1994).

All in all, the restoration of native plant communities is appropriate in the selection and juxtaposition of trees.

## Shrubs

The relative composition of shrubs, unlike trees, has not been pre-determined in the proposed planting plan. We are not able to compare and comment on the shrub compositional differences between planting plan and the composition of native ecoregion.

In showing the native species composition, BC Ministry of Forest (1994) distinguished herbs from shrubs (which we did not in our project). As such, the composition of what we defined as "shrubs" are expressed as "shrub composition" (Figure 5.5) and "herb composition" (Figure 5.6). Since we are not able to find the raw numerical data, we do not know the relative prevalence of "shrubs" versus "herbs".

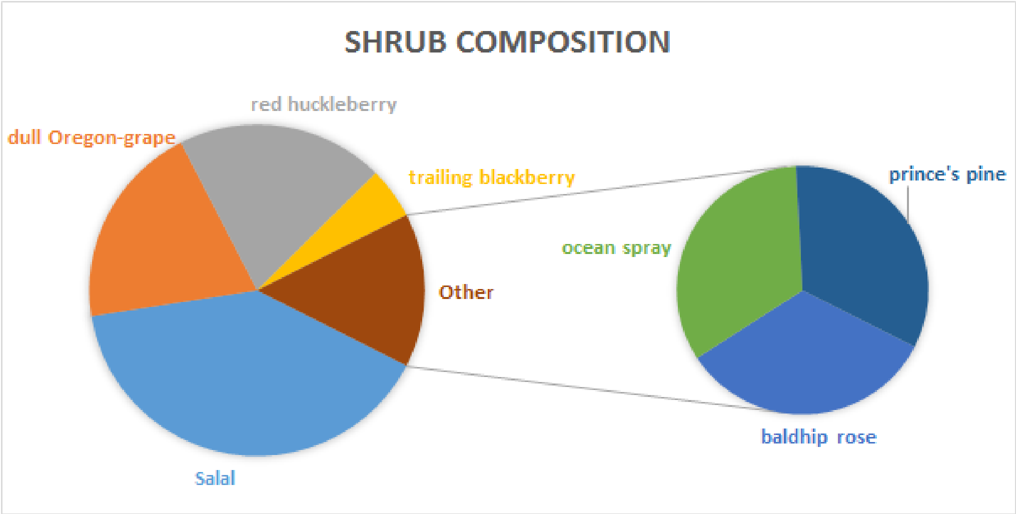



**Figure 5.5.** Native shrub composition in Point Grey, Vancouver. Adapted from Land Management Handbook 28, Ministry of Forests, BC (1994).

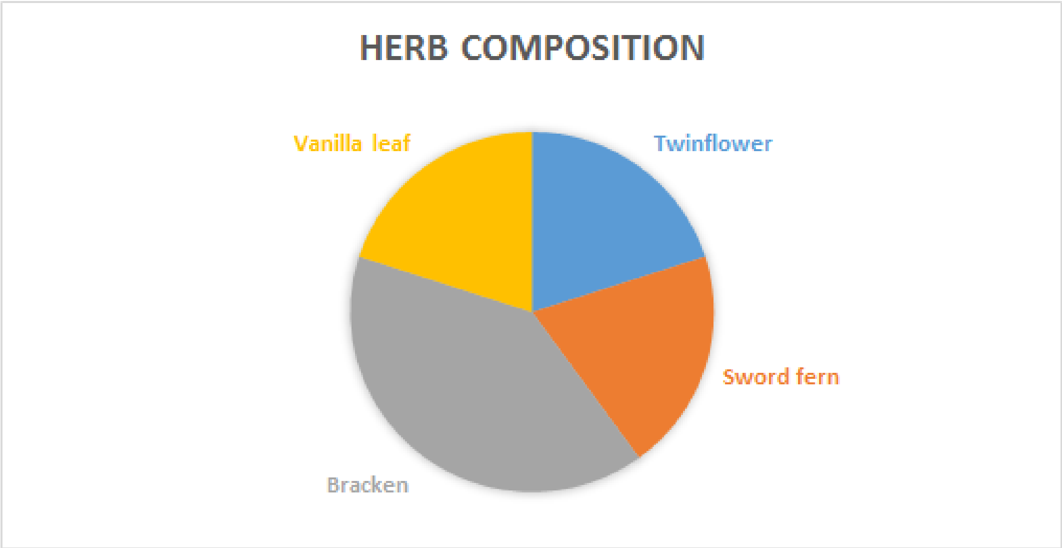



**Figure 5.6.** Native herb composition in Point Grey, Vancouver. Adapted from Land Management Handbook 28, Ministry of Forests, BC (1994).

The most prevalent species from the 2 plots are: salal, dull-Oregon grape, and bracken fern. Salal and dull-Oregon grape are appropriately utilized in the planting plan, thus ensuring hardy species adapted to the region's environment. Bracken fern, however, is excluded from the plan likely because of its high-reproducing nature. It is not commonly used for gardening and landscaping because it spreads very quickly and outcompetes other vegetation. Instead, sword fern is the only species from the ideal herb composition used on Sustainability Street. Note that these species are all adapted to partially-shaded to shaded environments, and grow best under canopy shade—in our cases, under Douglas-fir, Western red cedar, Pacific madrone, and Vine maple. They would not do well if they were not planted under tree shading.

On the contrary, non-native, ornamental plants (e.g. Karl foerster) should not be planted together with the native plants under canopy shade. It is likely for the native plants to spread and outcompete the non-native accent plants—this would defeat their ornamental purposes if they were to die. In general, it is not recommended to plant species with salal and dull-Oregon grape (other than themselves).

Some species on the "ideal composition" are unavailable for landscaping and gardening purposes (for example, red huckleberry can only spread naturally, or be planted commercially). Some are also unsuitable for gardening for a variety of reasons. For example, trailing blackberry is not an ideal choice for landscaping as it is very aesthetically messy. Thus we feel that the three main species the planting plan (salal, dull-Oregon grape, and sword fern) has adequately represented the native ecoregion.

There are some shrub species on the planting plan (Appendix B) which are not part of the "ideal shrub composition" (Figure 5.5, Figure 5.6). These tend to be species which are sun-loving and prefer a dry environment. This does not necessarily mean those species are unsuitable for Sustainability Street. Most areas of Vancouver were previously covered by forests and therefore shaded by canopy closure— this is why the "ideal shrub compositions" are dominated by shade-loving species. Sustainability Street, however, is not a forest; it is an urban environment without full canopy coverage. The planting plan's adaptation to include some sun-loving native and non-native (but non-invasive) shrubs not commonly found in forests is, in fact, appropriate.

All in all, the shrub selection is appropriate for the native landscape. However, whether the planting plan will score well on SITES Credit 4.9 is ultimately determined by the specific placements of each shrub relative to the canopy (which has not been determined by UBC yet). A higher score will be received if native shrubs are planted in proximity to the native trees. It makes sense from a practical stand point -- for example, if salal is evolved to grow well under native tree shade, it would likely grow with more rigor and less required maintenance if it is left in its preferred environment.

## Grass

Grasses are generally not present in native plant communities in Vancouver, except on disturbed sites. However, grasses cover only a very small area of the planting plan for Sustainability Street (roughly 2%), and as such do not have a significant impact on the street's performance on SITES.

## *5c. Conclusion and Recommendations*

In summary, the new planting plan for Sustainability Street performs well on all 3 SITES criteria for native species. On the planting plan:

- Most species are native to Southwestern BC and adapted to Vancouver's climate.
- Species composition adequately represents both the ideal native species composition in undisturbed forested landscape, and what is most appropriate for urban landscapes.
- Specific species such as Pacific Madrone attract wildlife and pollinators, which is desirable as a wildlife refuge.

In order to meet SITES criteria to "plant appropriate species in the most appropriate places", as well as "restoring plant communities native to the ecoregion", some specific recommendations are made below:

- Modify planting plan in order to:
    - Avoid planting Pacific madrone on the downslope area contouring the depression, where stormwater drains into.
    - Ensure all Cornus 'Eddie's White Wonder' Dogwood are planted in the shade of large trees such as Douglas-fir, Western red cedar and Pacific madrone, due to its susceptibility to diseases when under stress.
    - More Vine maple should be planted under shade (e.g. under Douglas-fir), instead of in the more open areas

- Once specific planting locations of shrubs have been determined:
    - Ensure that sword fern is primarily planted under Vine maple near the stormwater depression
    - Separate the ornamental plants from the major native plants such as salal, dull-Oregon grape, and sword fern
    - Under Pacific madrone, plant primarily salal and dull-Oregon grape, which are drought-resistant and adapted to Vine Maple's constant shedding of leaves

- It is highly advised to consult with UBC Plant Operations to determine the appropriateness of microhabitat for each shrub species after all specific planting locations are drafted. This helps to maximize planting success and the longevity of species on Sustainability Street, given maintenance constraints

Other considerations include proximity planting issues for researchers in the UBC Greenhouse. This is discussed in Appendix C. In general:

- Avoid planting Pacific madrone and Douglas-fir in proximity to the Horticulture Building
    - In replacement, plant Vine maple, which is both suitable for the stormwater depression environment and less problematic for the greenhouse
- Avoid planting the shrub species considered inappropriate (salal, beach strawberry, creeping Mahonia, clustered wild rose, Dwarf arctic willow, evergreen huckleberry) close to Horticulture Building, and instead utilize other shrub species.

# 6. BIOMASS RESTORATION

## *6a. Background Information*

### Significance of appropriate vegetative biomass

Establishing regionally appropriate vegetative biomass in a site can support the ecosystem services provided in that area. Studies have shown that a high plant biodiversity is needed to maintain ecosystem functioning and services (Isbell et al, 2011). Different species promote different services at different scenarios. It is therefore crucial for a site to maintain a high biodiversity to maintain multiple services at multiple scenarios.

Biomass Density Index (BDI) can be used as an approximate indicator of the ecosystem services for a landscape. A larger amount of vegetation present is usually correlated with higher numbers of more productive ecosystem services provided in a site (Calkins, 2012). BDI calculates the plant density by multiplying the assigned biomass density values for each vegetation type zone by the percent of total area for that zone.

### SITES Guidelines for biomass restoration

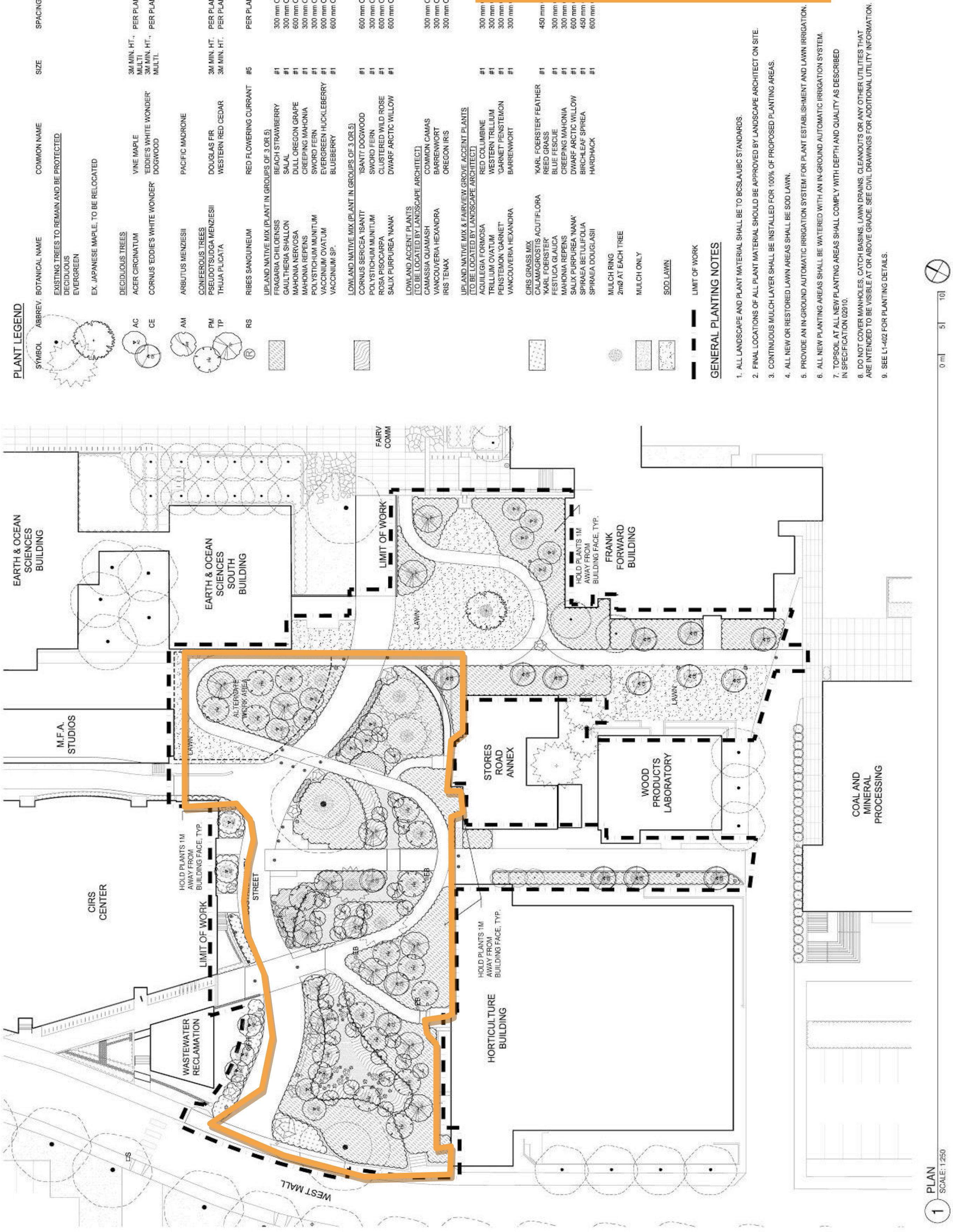
| Guideline | Objective |
|---|---|
| **4.6- Restore appropriate plant biomass on site** | Restore appropriate vegetative biomass to support ecosystem service benefits. Requires site map demonstrating existing and planned site conditions, and calculations for existing Biomass Density Index (BDI) and Planned Site BDI |

## *6b. Analysis and Discussions*

The existing BDI for the proposed site greatly exceeds that of the planned site, due to a large increase in trees with understory and a corresponding decrease in grass (Figure 6.1, Figure 6.2, Table 6.1, Table 6.2).


**Figure 6.1.** Map showing surveying results for the biomass composition at Sustainability Street. Field data is collected by our team. See Appendix A for more information on how the data is collected.

**Figure 6.2.** The prepared planting plan (Kiest, 2013) showing biomass composition of trees, shrubs and grass. Area of interest is enclosed in orange.



| Land cover /vegetation type zone | Biomass density value for this zone | Percentage of total site area for this zone | Biomass density value x percent of total site area |
|---|---|---|---|
| Trees with understory | 6 | 1% | 0.06 |
| Trees without understory | 4 | 25% | 1 |
| Shrubs | 3 | 4% | 0.12 |
| Grass | 2 | 50% | 1 |
| Bare ground not shaded by vegetation | 0 | 25% | 0 |
| Site BDI Value | | | **2.18** |

**Table 6.1.** BDI for existing conditions of Sustainability Street.

| Land cover /vegetation type zone | Biomass density value for this zone | Percentage of total site area for this zone | Biomass density value x percent of total site area |
|---|---|---|---|
| Trees with understory | 6 | 60% | 3.6 |
| Trees without understory | 4 | 3.75% | 0.15 |
| Shrubs | 3 | 9% | 0.27 |
| Grass | 2 | 2.25% | 0.05 |
| Bare ground not shaded by vegetation | 0 | 25% | 0 |
| Site BDI Value | | | **4.07** |

**Table 6.2.** BDI for planned conditions of Sustainability Street.

Note that SITES assign the highest biomass density values for trees. This is because studies have shown that tree species richness is positively correlated with multiple ecosystem services such as tree growth, carbon storage, biodiversity in the understory storage, etc. Biomass production and its subsequent ecosystem services can be 50% greater with 5 than with 1 tree species (Gamfeldt et al, 2008). As such, SITES assign the highest biomass density value for trees.

In addition, different land covers (i.e. tree canopy, shrubs), provide different services. It is therefore the most beneficial for a site to have higher diversity in order to provide a wide range of ecosystem services. For this reason, trees with understory are assigned a higher biomass density value than trees without understory or shrubs or grass.

The new site plan would replace most grass on Sustainability Street with shrubs, trees and understory (Figure 6.3). Tree cover would increase from 25% to more than 60%; and would mostly be surrounded by shrubs and understory. This change nearly doubles the BDI for the site, after renovation (Tables 6.1 and 6.2).

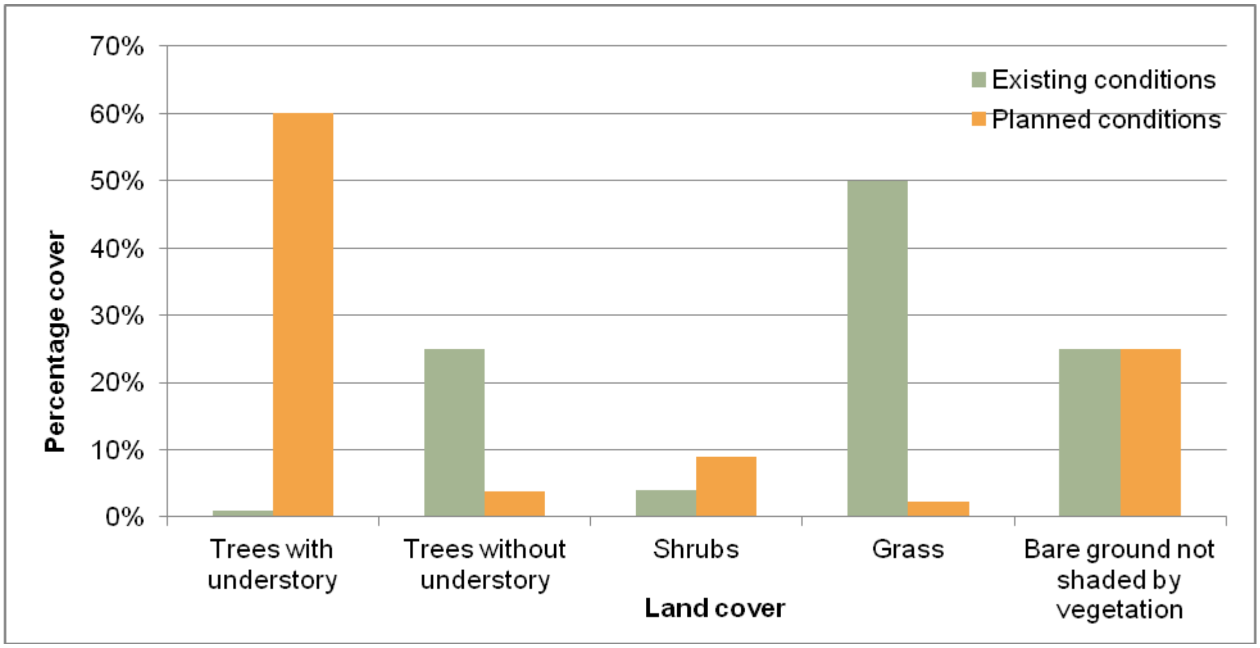



**Figure 6.3.** Bar chart showing differences in land cover of Sustainability Street between existing and planned conditions.

Note that SITES suggests we base the BDI analysis on the vegetation coverage 10 years from now. However, it is difficult to estimate the growth of trees and shrubs in 10 years, especially when we consider the current climatic variations. Therefore, the biomass density and BDI we have provided would be of the lower, more conservative range, under the assumption that the canopy cover would not increase significantly.

Overall, the new site plan shows great improvement from the existing conditions by generating higher diversity and various ecosystem services.

## Credits awarded

For Credit 4.6, SITES has provided specific information regarding how points are awarded (Figure 6.4). SITES indicate that we should compare the existing site BDI and the planned site BDI according to the terrestrial biome we are located in, which would be Temperate Conifer Forest Biome.

| TABLE 4.6-E | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Planned Site BDI | | | | | |
| | | 0–1 | 1–2 | 2–3 | 3–4 | 4–5 | 5 or above |
| Existing Site BDI | 0–1 | No Credit | 3 points | 5 points | 8 points | 8 points | 8 points |
| | 1–2 | No Credit | No Credit | 3 points | 5 points | 8 points | 8 points |
| | 2–3 | No Credit | No Credit | No Credit | 3 points | 5 points | 8 points |
| | 3–4 | No Credit | No Credit | No Credit | No Credit | 3 points | 8 points |
| | 4–5 | No Credit | No Credit | No Credit | No Credit | No Credit | 8 points |
| | 5 or above | No Credit | No Credit | No Credit | No Credit | No Credit | 8 points |

**Figure 6.4.** Point value table for sites in temperate conifer forest biome. Points are awarded according to the difference between Existing Site BDI and Planned Site BDI. Adapted from SITES (2009).

The existing site BDI is 2.18. The planned site BDI is 4.07. As such, **the new Sustainability Street would be awarded a range of 5 credits (out of 8 possible credits).**

## *6c. Conclusions and Recommendations*

The planned renovations for Sustainability Street significantly improve the site's BDI. The increase in BDI (from 2.18 to 4.07- 5.52) shows that Sustainability Street is able to support a higher biomass density which in turn provides more ecosystem services.

- Most categories show improvement: increased percent land coverage with higher biomass density, i.e. trees with understory, shrubs; decreased percent land coverage with lower biomass density, i.e. grass.
- The only category that shows no improvement is bare ground.
  .
  - It is likely that tree canopy will cover bare ground in 10 years' time. It is estimated that trees with understory will approach 75% of total site area by then.
  - Planned site BDI will then become ~5, and sustainability street will achieve 8 /8 points

For the time being, it is worthwhile to consider implementing more grass permeable pavers as replacements for concrete on Sustainability Street. They would be calculated as "grass" rather than "bare ground" under SITES criteria, thereby increasing the site BDI. The ecosystem being supported can act as a natural stormwater system that collects rainfall and filters contaminants.

# 7. SOIL PROTECTION AND MANAGEMENT

## *7a. Background Information*

**Importance of healthy soil**

There are two major benefits regarding to the maintenance of soil health: protecting valuable soil functions and reducing restoration or maintenance costs (SITES, 2009). SITES (2009) defines healthy soil as soil that has not been significantly disturbed by previous human development activities: for example, having uncompacted soil, and organic matter and chemical characteristics similar to that of reference soil.

Healthy soils can provide a wide range of valuable soil functions and further promote ecosystem services. Soil acts to regulate the hydraulics of the system by controlling the rates of water loss, utilization, contamination and purification (Brady and Weil, 2004). Soil also functions to recycle and assimilate elements within the system.

Healthy soils increase water holding capacity, improve drainage and are more well-buffered to pH changes. They are also better at retaining water and nutrients which reduce the needs of irrigation and the use of fertilizers. The use of large amounts of fertilizers and irrigation can cause a lot of adverse effects such as pollution, health problems and destruction of natural habitats (Pimentel, 1995). Maintaining soil health can also stimulate healthier, more extensive root development which in turn prevents wind and soil erosion. Maintenance costs are greatly reduced once healthy soils are established.

As such, the SITES guidelines for soil focus heavily on protecting soil health—establishing vegetation and soil protection zones, ensuring heavy machinery does not compact the soil, etc.

**SITES guidelines for soil protection and management**

| Guideline | Objective |
|---|---|
| **4.3: Create a soil management plan** | • Identify soil health: if soil has been disturbed by previous development<br>• Identify areas to be designated as Vegetation and soil protection zones (VSPZ) prior to construction<br>• Indicate locations of laydown and storage areas and vehicle parking during construction<br>• Ensure soil will be protected from compaction<br>• Describe treatment details for soil restoration |

## *7b. Results and Discussion*

## Identify areas to be designated as Vegetation and soil protection zones (VSPZ)

UBC technical guidelines (2013) defines Tree Protection Zones as the enclosure of a tree's critical root zone by Tree Protection Fencing, established in order to protect roots from damage by excavation (Figure 7.1). It is analogous to the *Vegetation and Soil Protection Zone (VSPZ)* designated by SITES (2009). The critical root zone is an approximation of a tree's root extension below ground, and is estimated by the greater of (1) extension from trunk to dripline[5], or (2) the distance from trunk to 1.5 times the diameter at breast height, *DBH*[6]. Utilizing the concept of critical root zone, the area in Sustainability Street designated as protection zones have been pre-determined and located in Figure 7.1. The protection zones surround trees currently on Sustainability Street.

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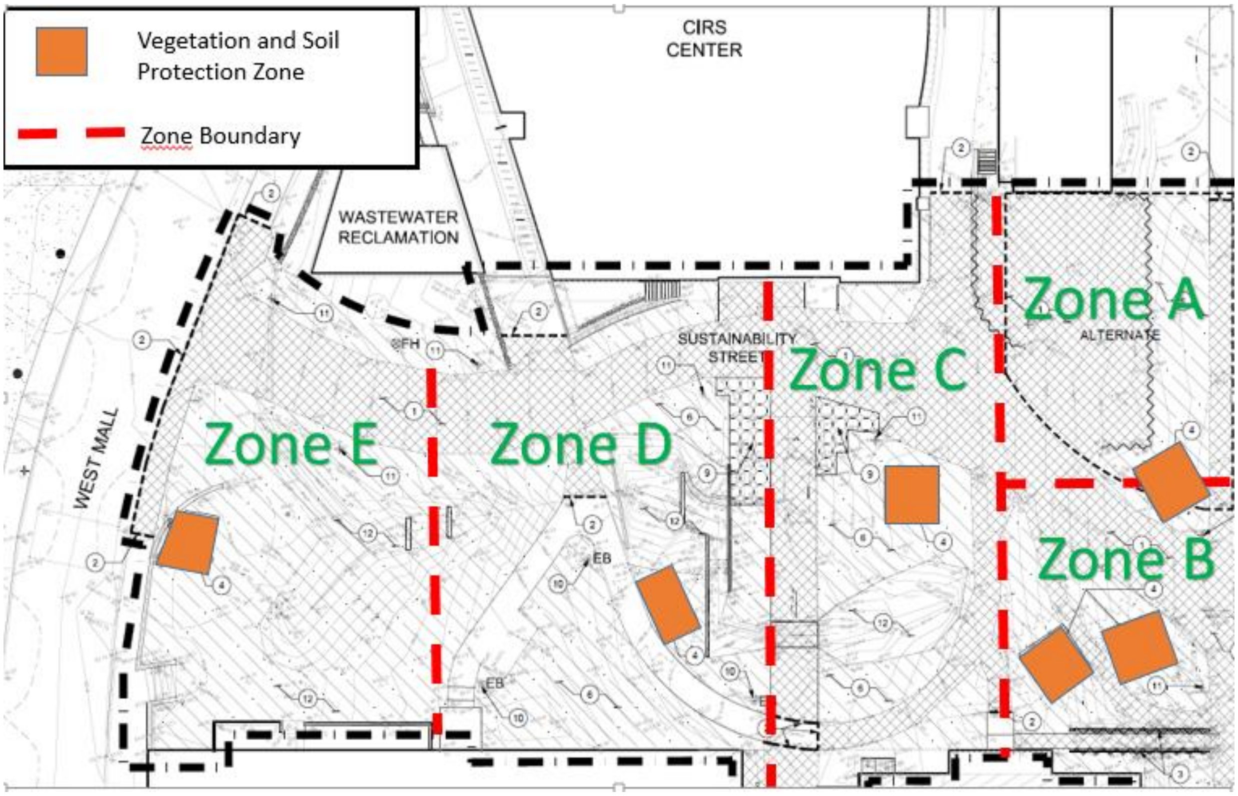


**Figure 7.1.** Map depicting vegetation and soil protection zone, highlighted in orange box (adapted from Kiest, 2013). Soil sampling zones are indicated. See methodology in appendix for rationale in zoning.

Where Tree Protection Zones are designated, orange snow fencing would be placed, fastened to metal stakes or a 2 x 4 wood frame. The height would be 4', and the width is determined by the location of dripline or the distance of 1.5 times the DBH (as discussed above). In addition to the fencing, erosion control devices would also ideally be installed to prevent erosion within the

5 **Dripline**- a ring around the tree canopy on the ground level that receives most of the rainwater shed from the tree canopy (USDA, n.d.)

6 **Diameter at breast height**- a standard method for determining the diameter of trunk of a tree. The breast height is typically measured at roughly 4.5 feet, 137cm

tree protection zones. Should the tree protection fencing be infeasible, alternative strategies must be developed with the Project consulting Arborist or UBC Campus Arborist.

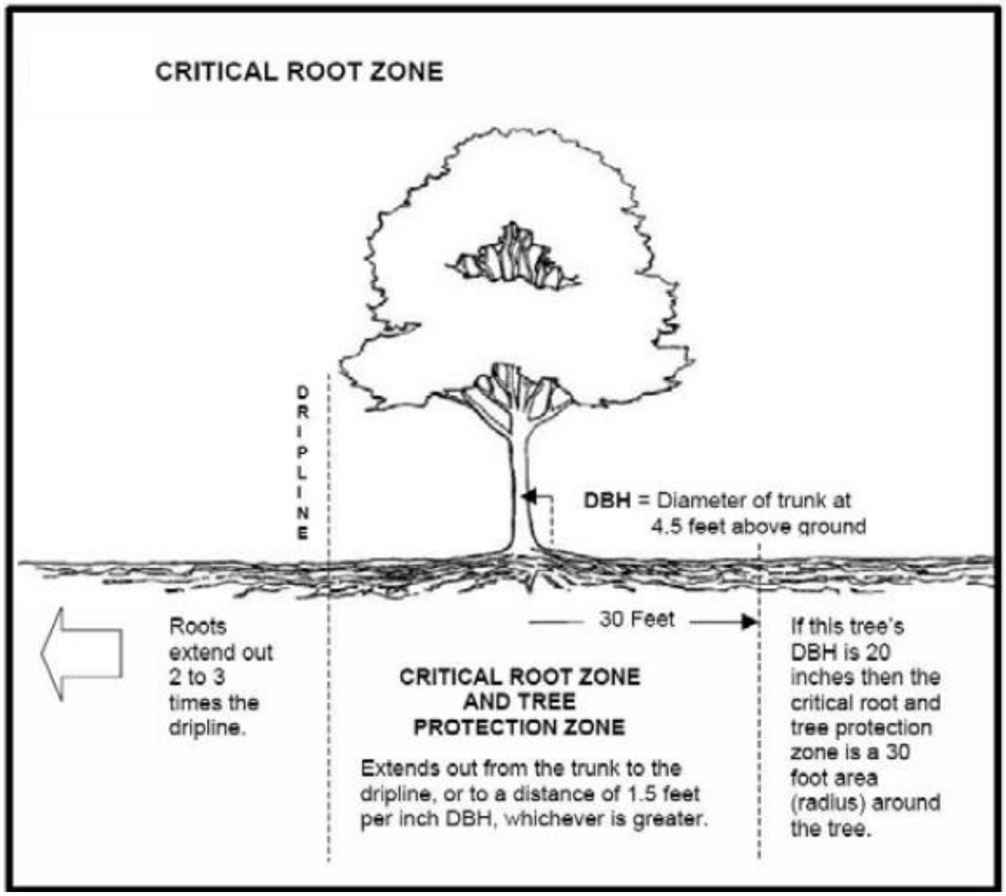


**Figure 7.2.** Diagram showing critical root zone. Adapted from UBC technical guidelines (2013).

## Identify soil health: if soil has been disturbed by previous development

Previous developments consist of logging in the 1890s, turning the coniferous forest into a pasture or lawn (Figure 3.2). The street does not appear to have been altered significantly since, so the soil is likely to have been minimally disturbed. In general, the soil on Sustainability Street is adequately healthy.

In general, the soil properties are adequately similar to that of reference values in UBC (Table 7.1). Reference data indicates that the soils in UBC are Bose soil, whose parent materials are glacial till and glacialfluvial deposits, and thus soil texture is usually gravelly loamy sand— this is consistent with data we have collected. In general, Bose soils are moderately well to well-drained, and have low water-holding capacity (Kelley and Spilsbury, 1939; Lavkulich and Rowles, 1971). The soil is also commonly acidic. As the soil texture is loamy sand and the bulk density is below the maximum allowable bulk density recommended for loamy sand (roughly 1.66 g/cm$^3$), soil compaction is not an area of concern.

| Property | Area | Site Values | Reference Values | Comments for Site Values |
|---|---|---|---|---|
| Soil Texture | A+B | Loamy Sand | Loamy Sand | - |
| | C | | | - |
| | D | | | - |
| | E | | | - |
| Bulk Density (g/cc) | A+B | 0.97 | 1.0 | Not compacted |
| | C | 0.99 | | Not compacted |
| | D | 0.88 | | Not compacted |
| | E | 0.99 | | Not compacted |
| pH | A+B | 6.7 | 5.5 | Neutral |
| | C | 5.8 | | moderately acidic |
| | D | 5.9 | | moderately acidic |
| | E | 5.8 | | moderately acidic |
| Estimated Electrical Conductivity (mmhos/cm) | A+B | 0.64 | No Data | Ideal |
| | C | 0.48 | | Ideal |
| | D | 0.52 | | Ideal |
| | E | 0.44 | | Ideal |
| Organic matter content (%) | A+B | 6 | 9.8 | sufficient |
| | C | 8.4 | | sufficient |
| | D | 10.5 | | sufficient |
| | E | 7.6 | | Sufficient |
| Total Nitrogen (%) | A+B | 0.21 | 0.44 | sufficient |
| | C | 0.37 | | sufficient |
| | D | 0.39 | | sufficient |
| | E | 0.28 | | sufficient |
| Available Phosphorus (ppm) | A+B | 53 | 77.7 | High |
| | C | 133 | | Excessive |
| | D | 153 | | Excessive |
| | E | 120 | | Excessive |
| Available Potassium (ppm) | A+B | 110 | No data | low |
| | C | 90 | | low |
| | D | 155 | | medium |
| | E | 140 | | low |
| Available Calcium (ppm) | A+B | 1650 | | appropriate |
| | C | 1800 | | - |
| | D | 2000 | | - |
| | E | 1500 | | - |
| Available Magnesium (ppm) | A+B | 120 | | medium |
| | C | 145 | | medium |
| | D | 175 | | medium |
| | E | 215 | | medium |

**Table 7.1.** Soil data of Sustainability Street obtained from field sampling, Data is compared with the reference data in UBC from Lavkulich and Rowles (1971). Data interpretation is aided by soil test interpretation guides by Horneck *et al.* (2011) and Dinkins and Jones (2007).

The organic matter content is also sufficiently similar to reference soil data and adequate to support soil structure and water-holding capacity, as the recommended organic matter content for temperate soils is 3-5% (Calkins, 2012). The electrical conductivity is low and therefore ideal—excess soluble salts in soil (represented by high electrical conductivity), can cause water deficits and plant desiccation.

pH is one property which differs noticeably between current conditions, 5.8 to 6.7, and reference soil, which is 5.5 (Table 7.1) . Altering pH would be costly and unsustainable, as it requires repeated treatment with elemental sulfur (Calkins, 2012). Moreover, the species in planting plan are able to tolerate a slightly higher pH than reference environment, it is not necessary to lower the pH (E-flora BC, n.d.).

It is not known why there is an excessive amount of phosphorus and a shortage of nitrogen compared to reference soil. Although there is an excess of phosphorus which would cause high phosphorus content in rain runoffs (and thus should be removed via wastewater treatment in the landscape's stormwater collection system), it does not pose any potential issues to future plantings. The soil is short of nitrogen compared to reference soil, but it is still considered "sufficient" in terms of fertility (Table 7.1).

Lastly, reference values for the available nutrients potassium, calcium, and magnesium are expressed in term of meq/100, and our lab results in ppm. We are not able to perform the conversion due to a lack of information about our sample weight, so we cannot make comparison about similarities between our soil and reference soils. Instead, we interpreted our data for available nutrients in terms of soil fertility, using soil test interpretation guides by Horneck et al. (2011) and Dinkins and Jones (2007). The soil test interpretation guides indicate that the available calcium and magnesium on Sustainability Street's soils are appropriate for plant growth. However, the soil has low potassium concentrations (Table 7.1). It is essential to understand that potassium tend to have lower concentrations in slightly acidic soils due to speciation (Calkins, 2012; Brady and Weil, 2010). However, potassium is indeed essential to plants' adaptation to environmental stresses: drought tolerance, winter hardiness, resistance to fungal diseases, etc, and therefore the application of fertilizer tablets with potassium during planting may be a remediation measure. This ensures the plants will have sufficient potassium during growth, without the need of further ongoing maintenance. It also poses no ecological risks to the environment. Potassium is not known to cause any off-site environmental problems; it's non-toxic and causes no eutrophication in aquatic systems (Brady and Weil, 2010)

Overall, aside from a shortage of potassium potentially negatively affecting plants' adaptation to stresses, the soil is healthy and has no special areas for concern.

**Indicate locations of laydown and storage areas and vehicle parking during construction**

During construction, the parking and storage areas is most likely to be in the parking lot adjacent to CIRS, or areas on Stores Road that is covered by concrete roads (Gregory, D., personal communication). Specific locations have not been identified.

**Ensure soil will be protected from compaction**

UBC technical guidelines (2013) ensures that if temporary access roads must pass over Tree Protection Zones, a road bed of 6-10" depth must be created using wood chip mulch and supportive mat of boards and other rigid materials. This measure prevents soil compaction and root damage in protection zones.

In addition, soil compaction is not commonly an issue with sandy soils due to the high porosity of coarse grained sands. As discussed in the previous section, the maximum allowable bulk density of UBC's loamy sand soil is roughly 1.66 g/cm$^3$. Our soil analysis (Table 7.1) has shown that Sustainability Street's soil is around 0.88-0.99, which is well-below the maximum allowable bulk density. As such, beyond the road bed indicated above for temporary access roads, no additional treatment for compaction is necessary.

However, care should be taken to avoid construction in the winter months, in order to best protect the soil from compaction. Vancouver experiences low pressure weather systems in winter months, which causes consistently rainy weather. Exposing bare soil to excess rain, and then subjecting the soil to construction activities is highly damaging to the soil and are a likely cause of compaction (Calkins, 2012).

### Describe treatment details for soil restoration

According to the planting plan and UBC technical guidelines (2013), UBC would add growing media, organic matter and mulches to the soil. The details are described below.

On Sustainability Street, there are currently invasive species as well as species not listed on the new planting plan. As such, for the renovation it is necessary to clear and grub all undesired vegetation within the top 450mm (Kiest, 2013). Following such soil disturbance, the proposed site plan indicates that “topsoil at all new planting areas shall comply with depth and quality as described in specification 02910”, and that “continuous mulch layer shall be installed for 100% of proposed planting areas” (Kiest, 2013).

Specification 02910 of UBC Technical Guidelines (2013) indicates that on-site topsoil must be assessed, amended and protected from compaction and weed infestation. In addition, growing medium, soils made to assist plant growth, will be added prior to planting. The growing medium will be specially formulated and tested by Pacific Soil Analysis, and would be composed of lab-approved proportions of mushroom manure / peat moss mix, silt and clays, and sand. Adequate organic matter comprised of mushroom manure, compost, and peat will be added to ensure sufficient organic matter proportions. Organic matter can improve water-holding capacity, drainage, and soil microorganisms, which ensures healthy soils can support plant growth.
The mulch layer installed for all proposed planting areas would be composted bark mulch (with no Douglas-fir and Hemlock bark chips and Cedar chips) of a lab-approved composition. Mulches are valuable for long term soil rehabilitation, which not only help maintain soil organic matter levels, but also increase water retention, temperature regulation, weed growth reduction, erosion limitation (Brady and Weil, 2010; Calkins, 2012).

There is no documentation on the specific growing media, organic matter, and mulches that would be added to the soil on Sustainability Street during construction. However, the information provided from UBC Technical Guidelines (2013) ensures that the contractors will comply with the aforementioned requirements.

## 7c. Conclusions and Recommendations

In general, the UBC Technical Guidelines (2013) have addressed SITES' (2009) expectations for soil management:

- Vegetation and Soil protection zones have been identified and a guideline for protection has been established.
- Storage and laydown sites are unofficially identified and thus, parking of heavy machinery would not impact the soil.
- In addition, the soil appears to be minimally disturbed and adequately healthy in organic matter, compaction (or lack thereof), electrical conductivity, and soil nutrients.
- As the soil is adequately healthy, no special measures are needed to “restore” soil health.
- However, grubbing of top layer is necessary to remove invasive species, along with their seed bank, as well as existing species that are not present in new planting plan. It is crucial for UBC to ensure the proper use of growing media, addition of organic matter and continuous input of mulches in order to protect the disturbed surface layer.

We feel that the measures planned by UBC will fully fulfill SITES' requirement, so no additional recommendations for SITES are necessary. Here are 2 points to be aware of:

- It would be helpful to have potassium fertilizer tablets during planting to ensure sufficient potassium for plant growth—this is essential for the plants' resistance against pests and diseases.
- It is advised to avoid construction during the winter months to minimize damage to soil.

However, to gain additional credits for Credit 4.4: Minimize soil disturbance in design and construction, which is not fully addressed on this report, detailed soil mapping must be performed. Please note that such soil mapping is costly, time-consuming, and labour intensive (APBI200 Class Notes), we are not able to include this in our project. Instead, we have conducted composite sampling (see Methodology) to gain a basic understanding for soil health, which is sufficient for Prerequisite 4.3, but not Credit 4.4.

# 8. FINAL COMMENTS

In conclusion, Sustainability Street is likely to do well under SITES Guidelines and Performance Benchmarks (2009). Specifically:

- 87% of the current Sustainability Street is covered by non-native plants. Of the non-native plants, 9% are problematic noxious weeds
    - We have recommended a new active and realistic management plan to control invasive plants in order to receive higher score for prerequisite 4.1.

- In general, the new planting plan adequately addresses the SITES guidelines and will score well in prerequisite 4.2, credit 4.7 and credit 4.9.
    - Specific recommendations regarding locations of planting are made to further improve long term suitability of each plants.

- The new planting plan shows an improvement in establishing biomass density and achieves a high score of 5 to 8 out of 8 points (depending on how conservative the estimates are) according to the guidelines listed under credit 4.6.

- The planting plan fully addresses SITES concerns for prerequisite 4.3, the soil management plan, and no further recommendations are necessary

In practice, the success and longevity of Sustainability Street's native vegetation depend not only on the fulfillment of SITES criteria, but also on the level of maintenance undertaken (as suggested in Section 4: Invasive species and management). It is therefore essential to have a good level of communication and collaboration between landscape designers and plant operations staff, in order to ensure the selected vegetation will perform successfully under the given level of maintenance.

Overall, we feel that SITES would greatly assist with UBC's sustainable landscape design in the future. SITES successfully takes complex ecological ideas and summarizes into clearly identifiable, pursuable objectives. Using each of the SITES prerequisites and credits, future sustainable landscapes can be crafted, step by step, on the UBC campus.

# APPENDIX A: METHODOLOGY

## *Invasive Species and Management*

We collected data on the site's invasive species via an area survey of the vegetative species present. The site was divided into five sections, labeled A to E (Figure 7.1). Each section was surveyed individually, and any non-native species and their relative distributions in the area were recorded on a colour-coded site map. The species were first identified by morphological characteristics, which were subsequently recorded via photographs. The images were later used to confirm the identities of the species found. The area coverage of each species relative to the entire site was then calculated based on their distributions in each area, and mapped on a colour-coded map.

## *Native Species Communities*

As required by SITES Guideline 2009, we would look at the site plan prepared by UBC landscape architects, which includes a map of planting plan (Figure 3.4). The proposed planting plan shows each species that would be planted on Sustainability Street, and where they would be planted. For prerequisite 4.2, we performed background research on each species listed on the planting plan, to ensure they are native and appropriate, and summarize our findings in a table. We included the species native status into the table as well, as required by credit 4.7.

In addition, we performed literature search in order to understand the "ideal" species composition that would have been located in the landscape, if human disturbances have never happened. While Pacific Spirit Regional Park can give us a first-hand idea of what a native landscape would look like, B.C.'s Ministry of Forests has prepared a handbook (Land Management Handbook 28) which summarizes the ideal percentage composition of species for each ecozone, from which we extracted our data from (Greens and Klinka, 1994). The land management handbook utilizes the Biogeoclimatic Ecosystem Classification system, which will explained in detail below. Pie charts were made comparing the ideal species composition with the planned site species composition.

### Biogeoclimatic Ecosystem Classification

Biogeoclimatic Ecosystem Classification (BEC) is an ecosystem classification system consisting of 14 biogeoclimatic zones (Figure A1). It was first introduced in the University of British Columbia in 1949. Through further data collection and mapping efforts, it is later modified and adapted by BC's Ministry of Forests as an acceptable province-wide standard for biogeoclimatic ecological classification. It is continually being revised as new data come to light for regions not previously well-understood.

Each of the 14 biogeoclimatic zones can be broadly defined as a geographic area with similar soil and vegetation as a result of homogeneous climate, with different species that grow optimally. Subzones occur within each zone, which allows a more specific definition of plant communities' characteristics. Subzones can be further divided into variants, which indicate regional distribution based on climatic variations (e.g. *montane*, with higher elevation and cooler climate, and *submontane*, with lower elevation and warmer climate).

Specific regions are named after Zone-Subzone-Variant. For example, Point Grey, Vancouver's dominant climax vegetation is Coastal Western Hemlock, designated by CWH. Its precipitation is (relative to other CWH zones) is very dry, and its continentality/temperature being maritime, so its subzone code is xm. It's within the Southern region of the subzone, so it is designated by variant 1. Thus, Vancouver's biogeoclimatic zone is CWHxm1. BC's Ministry of Forests has mapped out the zones and subzones within different regions of British Columbia, so we would only need to refer to the handbooks provided by the ministry to figure out which zone Point Grey, Vancouver belongs in (Figure A2).

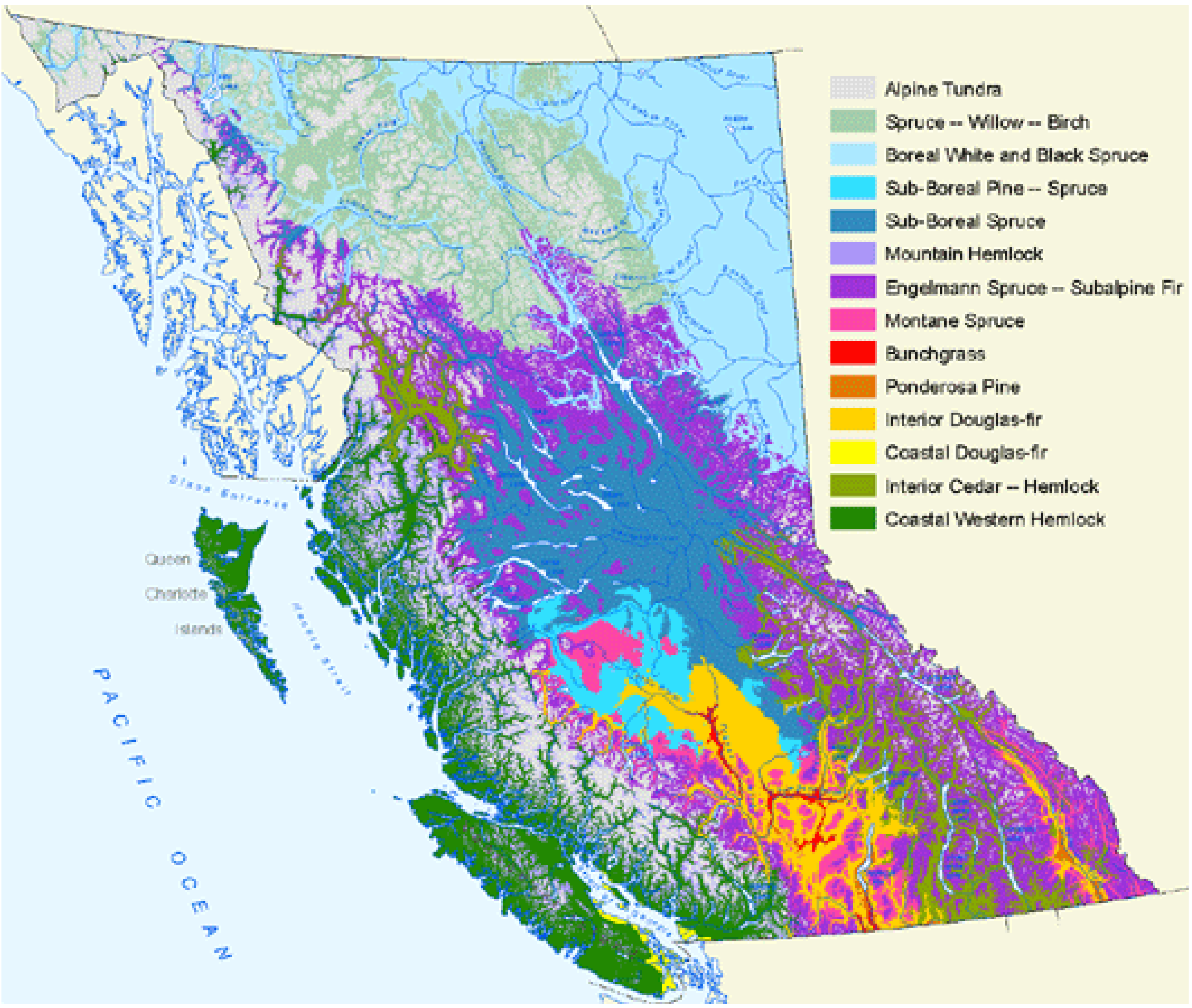

**Figure A1.** Biogeoclimatic zones in British Columbia (B.C. Ministry of Forests, 1994)

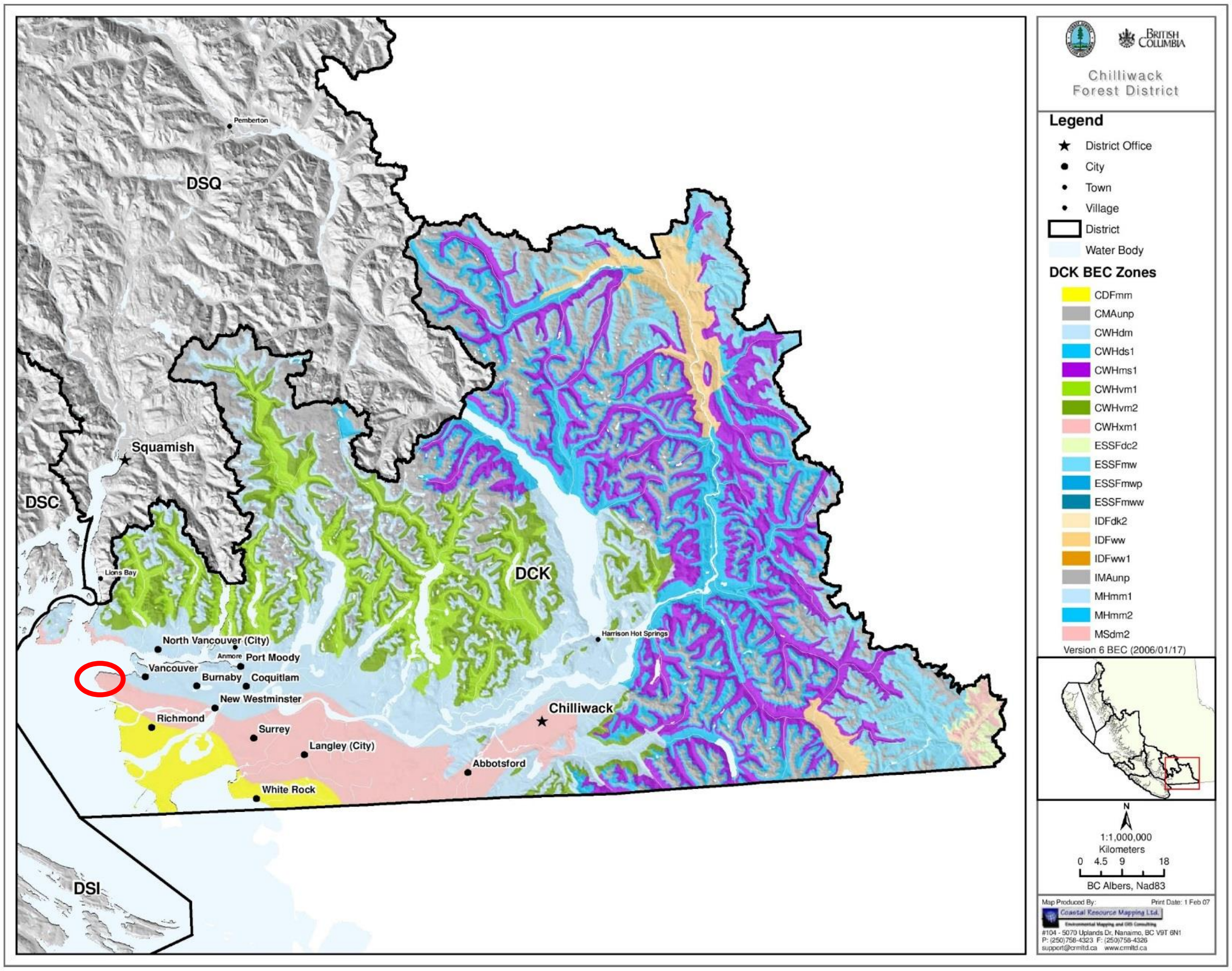


**Figure A2.** Zones in Vancouver Forest Region (B.C. Ministry of Forests). Point Grey campus, where Sustainability Street is located in, is circled in red, belonging to the pink region CWHxm1.

## *Biomass Surveying*

Data was collected on current plant biomass in Sustainability Street. Based on SITES (2009), there were five vegetation type zones: trees with understory, trees without understory, shrubs, grass, and bare ground not shaded by vegetation. The site was first divided into 5 area from A to E. For each area, we estimated the percentage coverage of each vegetation type zone. At the end, the data from areas A to E were combined to estimate the current plant biomass for the entire Sustainability Street. The same data was collected for the planned site using the prepared planting plan which included information on biomass composition of trees, shrubs and grass (Kiest, 2013). BDI for existing site and planned site were calculated using these data.

## *Soil Sampling*

In order to gain an understanding of existing soil conditions on Sustainability Street, field sampling was conducted.

The area of interest in Sustainability Street was divided into 5 segments: Area A, B, C, D, and E (Figure 7.1), from upslope to downslope. The choice of division was that each area has a distinctive set of species composition (usually invasive, as explored in Section 4: Invasive species and management), which may be indicative of slightly differing soil properties. Each area is also separated by narrow concrete passages.

Within each area (except Area A and B, which are combined in sampling due to small sampling area), composite sampling was performed, where 15 subsamples of 6” depth are collected by shovels, and thoroughly mixed in a bucket. This is a common soil sampling methodology to gain a first order understanding of site conditions, especially when time and budget are limiting factors. About 0.5L of thoroughly mixed subsamples are collected in a Ziploc bag and mailed to Pacific Soil Analysis for lab analysis. Parameters analyzed by the lab include: bulk density, pH, electrical conductivity, organic matter content, and nutrient contents. Locations of the 15 subsamples are determined randomly: by marking each area into grids, numbering each grid, and drawing numbers for subsampling using random number generator.

Resultant data is analyzed according to soil analysis interpretation guides by Horneck *et al.* (2011) and Dinkins and Jones (2007). In addition, values are compared to that of reference soil in UBC by Lavkulich and Rowles (1971). Reference data is taken in a UBC pasture, with similar history and vegetation as that of Sustainability Street, but prior to extensive campus renovation plans.

# APPENDIX B: DATA TABLES FOR SECTION 5

The following pages include summary tables, as required by SITES, for:

- Species on planting plan, and
- Properties, preferred environment, and native status of each species on planting plan

| | |
|---|---|
| Trees | Acer circinatum (Vine maple)<br>Cornus ‘eddie’s white wonder (Eddies white wonder dogwood)<br>Arbutus menziesii (Pacific madrone)<br>Pseudotsuga menziesii (Douglas-fir)<br>Thuja plicata (Western red cedar) |
| Shrubs | Fragaria chiloensis (Beach strawberry)<br>Gaultheria shallon (Salal)<br>Mahonia nervosa (Dull oregon grape)<br>Mahonia repens (Creeping mahonia)<br>Polystichum munitum (Sword fern)<br>Vaccinium ovatum (Evergreen huckleberry)<br>Vaccinium sp. (Blueberry)<br>Cornus sericea ‘islanti’ (‘Islanti’ dogwood)<br>Rosa pisocarpa (Clustered wild rose)<br>Salix purpurea ‘nana’ (Dwarf arctic willow)<br>Camassia quamash (Common camas)<br>Vancouveria hexandra (Barrenwort)<br>Iris tenax (Oregon iris)<br>Aquilegia formosa (Red columbine)<br>Trillium ovatum (Western trillium)<br>Penstemon ‘garnet’ (‘Garnet’ penstemon) |
| Grass | Calamagrostis acutiflora (‘Karl foerster’’ feather)<br>‘Karl foerster’ (Reed grass)<br>Festuca glauca (Blue fescue)<br>Mahonia repens (Creeping mahonia)<br>Salix purpurea ‘nana’ (Dwarf arctic willow)<br>Spiraea betulifolia (Birchleaf spirea)<br>Spiraea douglasii (Hardhack) |

**Table B1.** Summary table listing species in planting plan.

| Scientific name | Common name | Properties | Preferred Environment | Native Status |
|---|---|---|---|---|
| **Acer circinatum** | Vine maple | Deciduous; holds stream banks and eroding soils; no reported pests | Dry to moist with partial shade to shade | Native status (S5 provincial status) |
| **Cornus 'eddie's white wonder'** | Eddies white wonder dogwood | Deciduous; high hardiness; no reported insect and disease problems | Sun to partial shade | Native Cultivar |
| **Arbutus menziesii** | Pacific madrone | Not tolerant of the urban environment; drought tolerant; severe damage by a fungus, e.g. madrone canker; susceptible to insects and disease | Dry with full sun to partial shade | Native status (S5 provincial status) |
| **Pseudotsuga menziesii** | Douglas-fir | Fast growing; host to many native insects and birds | Dry to moist with full sun to partial shade | Native status (S5 provincial status) |
| **Thuja plicata** | Western red cedar | Long-lived; deep root system, tolerates a wide edaphic range | Moist to wet with partial shade to shade | Native status (S5 provincial status) |

**Table B2.** Trees on planting plan with their properties, preferred environment and native status.

| Scientific name | Common name | Properties | Preferred Environment | Native Status |
|---|---|---|---|---|
| **'Karl foerster'** | 'Karl foerster' feather | Can tolerate a wide range of soil types; no serious insect and disease problems | Moist to wet with full sun | Non-native, Not an invasive species on the BC invasives list |
| **Calamagrostis acutiflora** | Reed grass | Highly tolerant of urban pollution; can tolerate wide ranges of soil types and pH | Dry to moist with full sun to partial shade | Not an invasive species on the BC invasives list |
| **Festuca glauca** | Blue fescue | Drought and poor soil tolerant; short-lived; requires frequent division | Dry to moist with full sun | Not an invasive species on the BC invasives list |
| **Spiraea betulifolia** | Birchleaf spirea | Deciduous; can tolerate a wide range of soil types; susceptible to many disease and insects | Dry to moist with full sun | Native status (S5 provincial status) |
| **Spiraea douglasii** | Hardhack | Aggressive spreader under moist environments; susceptible to fire blight, leaf spot, powdery mildew, etc | Moist to wet with full sun to partial shade | Native status (S5 provincial status) |

**Table B3.** Grass on planting plan, with their properties, preferred environment and native status.

| Scientific name | Common name | Properties | Preferred Environment | Native Status |
|---|---|---|---|---|
| **Fragaria chiloensis** | Beach strawberry | Evergreen; low maintenance; fast growing; drought tolerant; fire resistant; no reported pests | Dry with full sun to partial shade | Native status (S4 provincial status) |
| **Gaultheria shallon** | Salal | Evergreen; very adaptable; does not transplant well; no reported insect and disease problems | Dry to moist with partial shade to shade | Native status (S5 provincial status) |
| **Mahonia nervosa** | Dull oregon grape | Evergreen; very adaptable; medium maintenance; susceptible to rust, leaf spots, galls and scale insects | Dry to moist with partial shade to shade | Native status (S5 provincial status) |
| **Mahonia repens** | Creeping mahonia | Evergreen; medium maintenance; susceptible to rusts, leaf spots and a few insect pests | Dry to moist with full sun to partial shade | Native status (S5 provincial status) |
| **Polystichum munitum** | Sword fern | Evergreen; low maintenance; adaptable to most site conditions, can tolerate acidic conditions near cedar | Dry to moist with partial shade to shade | Native status (S5 provincial status) |
| **Vaccinium ovatum** | Evergreen huckleberry | Evergreen; does not transplant well; drought tolerant; no reported pests | Dry to moist with partial shade to shade | Native status (S4 provincial status) |
| **Vaccinium sp.** | Blueberry | Tolerant of wide ranges of pH and high temperature | Moist to wet with full sun | Native status (S4 provincial status) |
| **Cornus sericea 'islanti'** | 'Islanti' dogwood | Deciduous; medium maintenance; susceptible to leaf, twig blights and some insect pests | Moist to wet with full sun to partial shade | Native cultivar |
| **Rosa pisocarpa** | Clustered wild rose | Fire resistant; low maintenance; spread by rhizomes or thicket-forming | Moist to wet with full sun to shade | Native status (S4 provincial status) |
| **Salix purpurea 'nana'** | Dwarf arctic willow | Deciduous; low maintenance; tolerates poor soil; susceptible to a number of foliar diseases and many insect pests, e.g. aphids, scale, etc. | Moist to wet with full sun | Non-native; Not an invasive species on the BC invasives list |
| **Camassia quamash** | Common camas | Fire resistant; perennial; no serious insect and disease problems | Dry to moist with full sun to partial shade | Native status (S4 provincial status) |
| **Vancouveria hexandra** | Barrenwort | Herbaceous perennial; poor performance in hot and dry summers; no serious insect and disease problems | Dry to moist with partial shade to full shade | Not an invasive species on the BC invasives list |
| **Iris tenax** | Oregon iris | Fire resistant; perennial; foliage or flowers can cause skin irritation or allergies | Moist to wet with full sun to partial shade | Not an invasive species on the BC invasives list |
| **Aquilegia formosa** | Red columbine | Perennial; can tolerate nutrient poor soils; no records of toxicity but belongs to a family with a few mildly toxic species | Dry to moist with full sun to partial shade | Native status (S5 provincial status) |
| **Trillium ovatum** | Western trillium | Perennial; fire resistant; drought tolerant; low maintenance | Dry to moist with partial shade to shade | Native status (S5 provincial status) |
| **Penstemon 'garnet'** | 'Garnet' penstemon | Evergreen perennial; long-living; can tolerate poor soils and alkaline conditions | Dry to moist with full sun to shade | Not an invasive species on the BC invasives list |

**Table B4.** Shrubs on planting plan, with their properties, preferred environment and native status. Species in blue belong to *Lowland Native Mix*, the species planted on the depression where stormwater drains into (exception: *Polystichum mutinum*, i.e. Sword Fern, are present in both Upland and Lowland Native mix.

# APPENDIX C: PROXIMITY PLANTING ISSUES FOR HORTICULTURE BUILDING

The horticulture building, located in proximity to Sustainability Street, hosts a greenhouse where horticultural research takes place. Many of the greenhouse plants are sensitive to external pests and diseases, which poses external bias to the data. A number of native species are hosts to such pests and diseases—while they may not pose significant issues to those host species themselves, they are problematic for the greenhouse plants.

Table C1 summarizes a list of species advised against proximity planting in Sustainability Street. Please note that 100% of tree species and 45% shrub species in Sustainability Street's proposed planting plan are considered inappropriate. This poses a challenge for planting designs. The proposed planting plan includes carefully chosen native species that are appropriate for both SITES criteria, site environmental conditions and design intent. To remove all of the species in question effectively cancels out all the significant players in the planting design. In addition, many of these species occur naturally and/or are planted around the building, regardless of Sustainability Street's plans. As such a compromise would include the removal of certain most problematic species.

We are not given information about the extent of damage each pest and disease does to the specific greenhouse research plants. Judging purely from numbers, it appears that Pacific madrone and Douglas-fir are the most problematic species for the greenhouse horticultural research. From a purely ecological standpoint, they are conveniently also the species we recommended against planting downslope of Sustainability Street, where the stormwater depression is located in (See Section 5: Native Species and Composition).

If a degree of compromise is to be reached, we recommend the following:

- Avoid planting Pacific madrone and Douglas-fir immediately outside the Horticulture Building (exact distance of avoidance is up to the landscape architect, depending on level of compromise reached).
  - In replacement, plant Vine maple, which is both a suitable candidate for the stormwater depression environment and a less problematic species for the greenhouse.
- Select species other than Salal, Beach strawberry, Creeping mahonia, Clustered wild rose, Dwarf arctic willow, Evergreen huckleberry immediately outside the Horticulture Building.

| *Scientific Name* | Common Name | Pests | Diseases |
|---|---|---|---|
| *Acer Circinatum* | Vine maple | Aphids, Spider mites, Scale, Lepodopterans | Verticilium Wilt |
| *Calamagrostis acutiflora* | Karl foerster feather | Host for thrips | N/A |
| *Carex sp* | Sedges | Mealy bugs and Scale | N/A |

| | | | |
|---|---|---|---|
| *Cornus seicea 'Elegantissima'* | Dog wood | Aphids, Scale | Mildew |
| *Cornus sericea 'isanti'* | Isanti Dogwood | Spider mite | N/A |
| *Cornus* | Eddie's white wonder | Horse chestnut scale | N/A |
| *Fragaria chiloensis* | Beach strawberry | Weevils | Phyllosticta leaf spots, Colletotrichum sp |
| *Gaultheria shallon* | Salal | Scale, Mealy bug, Whitefly | N/A |
| *Holodiscus discolor* | ocean spray | Spider mite | N/A |
| *Lonicera involucrata* | Local honeysuckle | thrips, aphids | N/A |
| *Mahonia repens* | Creeping Mahonia | | N/A |
| *Pseudotsudga menziesii* | Douglas-Fir | Douglas fir twig weevil, Douglas fir engraver beetle, Flat headed wood borer, Douglas fir beetle | N/A |
| *Reed Grass* | Karl Foerster | Aphids,Lleaf roller and Scale | leaf spot, fire blight, powdery mildew, root rot |
| *Rosa Psocarpa* | Clustered wild rose | Aphids, Caterpillars, Sawfly | N/A |
| *Salix purpurea nana* | Dwarf artic willow | Spider mite | N/A |
| *Sambucus racemosa* | Red elder berry | Aphids | N/A |
| *Spiraea densiflora* | mountain spirea | Aphids | Mildew |
| *Spirea betulifolia* | Birch leaf spirea | Aphids, caterpillars | powdery mildew |
| *Spirea douglasii* | Hardhack | Aphids | N/A |
| *Taxus brevifolia* | Pacific Yew | Aphids, Galls, Leaf miner insect, Nematodes, Scale insects, Stem borer insects, Thrips, Weevils, Spidermites | Anthracnose , Bacterial disease, Blight, Canker disease, Mildew powdery or downy, Root rot |
| *Thulja plicata* | Western Red cedar | Spider mite, Juniper scale, Arbovitae aphids | Keithia blight |
| *Vaccinium ovatum* | Evergreen Huckleberry | N/A | Phomopsis Twig Blight and Canker, Botryosphaeria Stem Canker, Fusicoccum Canker |
| *Vaccinium spp* | Blueberry | Scale | Leaf spot, twig blight |
| *Viburnum opulus var. americanum* | High bush cranberry | N/A | N/A |
| *Pacific madrone* | Arbutus | Fall web worm,<br>Tent Caterpillar,<br>Aphids,<br>Leaf minors,<br>Western ash borer | **Root Pathogens**<br>Damping-off<br>Collar rot or basal canker<br>Phytophthora root rot<br>Armillaria root disease<br>Annosus root rot<br><br>**Twig dieback and Branch Cankers**<br>Madrone canker |

| | | | |
|---|---|---|---|
| | | | Madrone twig dieback<br><br>**Wood-decay Fungi**<br>Brown top rot<br>Yellow root rot<br><br>**Foliage diseases**<br>Leaf spot<br>Tar spot<br>Spot anthracnose<br>Blister blight<br>Madrone foliage blight<br>Rust<br>Speckled tar spot |

**Table C1**. Excerpt from a list of plant recommended as inappropriate for proximity planting in Sustainability Street. Species highlighted in red are tree species present in planting plan, and species highlighted in purple represent shrub species in planting plan.

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